

Hydrogeological Report

US Highway 2 Groundwater Study S.R. 395 North Spokane Corridor Project Spokane, Washington

June 29, 2001

Prepared for

**The Washington State Department of Transportation
Olympia, Washington**

Prepared by



LANDAU ASSOCIATES, INC.

10 North Post St., Suite 218 • Spokane, WA 99201 • (509) 327-9737

TABLE OF CONTENTS

| | <u>Page</u> |
|--------------------------------------|-------------|
| 1.0 INTRODUCTION | 1-1 |
| 1.1 SITE DESCRIPTION | 1-1 |
| 1.2 PURPOSE | 1-1 |
| 1.3 SCOPE OF SERVICES | 1-1 |
| 2.0 INVESTIGATION METHODS | 2-1 |
| 2.1 FIELD METHODS | 2-1 |
| 2.1.1 Drilling and Well Construction | 2-1 |
| 2.1.2 Pumping Tests | 2-2 |
| 2.1.3 Water Quality Analysis | 2-3 |
| 2.2 PUMPING TEST ANALYTICAL METHODS | 2-3 |
| 3.0 FINDINGS AND RESULTS | 3-1 |
| 3.1 REGIONAL GEOLOGY | 3-1 |
| 3.2 PROJECT GEOLOGY | 3-2 |
| 3.3 PROJECT HYDROGEOLOGY | 3-3 |
| 3.4 PUMPING TESTS RESULTS | 3-3 |
| 3.4.1 Well US2-9-01 | 3-4 |
| 3.4.2 Well US2-4D-01 | 3-4 |
| 3.4.3 Well US2-10-01 | 3-4 |
| 3.5 PUMPING TEST ANALYSES | 3-5 |
| 3.6 SEEPAGE CALCULATIONS | 3-5 |
| 3.7 WATER QUALITY RESULTS | 3-7 |
| 4.0 SUMMARY AND CONCLUSIONS | 4-1 |
| 5.0 USE OF THIS REPORT | 5-1 |
| 6.0 REFERENCES | 6-1 |

APPENDICES

| | |
|---|---|
| A | Boring Logs |
| B | Laboratory Testing and Analytical Results |
| C | Pumping Test Data |

LIST OF FIGURES

| <u>Figure</u> | <u>Title</u> |
|---------------|---|
| 1 | Vicinity Map |
| 2 | Area Map Proposed US2/SR395 Interchange |
| 3 | Cross Section A - A' |
| 4 | Cross Section B - B' |

LIST OF TABLES

| <u>Table</u> | <u>Title</u> |
|--------------|--|
| 1 | Boring and Well Construction Details |
| 2 | Groundwater Elevation Summary |
| 3 | Pumping Test Summary |
| 4 | Pumping Test Results |
| 5 | Estimated Seepage Rates |
| 6 | Water Quality Testing Analytical Results |

1.0 INTRODUCTION

This hydrogeological report summarizes the field investigation and data analyses completed in support of the Washington State Department of Transportation (WSDOT) U.S. Highway 2 (US 2) groundwater study in Spokane, Washington. The purpose of this investigation was to obtain subsurface information to characterize soil and groundwater conditions near the proposed State Route (SR) 395/US 2 interchange, and evaluate and characterize the potential impacts of shallow groundwater on project design and construction activities.

1.1 SITE DESCRIPTION

The project location is shown on the vicinity map (Figure 1). As shown on Figure 1, the proposed SR 395 alignment extends north from Interstate 90 (I-90) west of Freya Street in Spokane Washington, and jogs west, connecting with existing SR 395 just south of the Little Spokane River bridge. The project site is located in the vicinity of the intersection of US 2 and Shady Slope Road, approximately ½ mile west of the town of Mead, Washington. The area map (Figure 2) shows the project area with the location of borings drilled for this investigation and for previous geotechnical investigations.

1.2 PURPOSE

As currently proposed, US 2 will become an underpass at the planned SR395/US 2 interchange, with cut depths of up to 35 feet (ft) between Shady Slope Road and Deadman Creek. Previous geotechnical field investigations encountered shallow groundwater within 20 ft of the surface near Shady Slope Road. Due to the anticipated cut depth in the US 2 underpass area, this hydrogeologic investigation was implemented to characterize groundwater conditions, estimate potential seepage rates that may be encountered during construction, and summarize preliminary dewatering options appropriate for temporary and long term control of shallow groundwater.

1.3 SCOPE OF SERVICES

Landau Associates was contracted by WSDOT to provide the services in accordance with the on-call geotechnical services Agreement No. Y-7373 between WSDOT and Landau Associates, Inc., Task AF, Work Order XL-1154, our February 12, 2001 scope and estimated cost letter, and our proposed subcontractor/subconsultant letter with a revised fee summary sheet dated February 26, 2001. The completed scope of services included the following specific tasks:

- Available hydrogeological data in the vicinity of US 2 from previous WSDOT field investigations, as well as hydrogeologic and geochemical data on file with the Eastern Region of the State of Washington Department of Ecology (Ecology) were reviewed.
- Field oversight and inspection services were conducted for the drilling and installation of six piezometers and one extraction well in the vicinity of the SR 395/US 2 interchange to characterize soil and groundwater conditions. One additional piezometer was drilled and installed for geotechnical purposes along the proposed SR 395 route.
- A conceptual model of the local hydrogeology was developed, and an aquifer test plan was prepared for WSDOT approval. Three groundwater samples were also collected to evaluate whether extracted groundwater would require containment during the test.
- Three pumping tests were conducted to gather data to estimate the hydraulic parameters of the water-bearing zones encountered during drilling. The pumping tests included step discharge, constant discharge, and water level recovery tests.
- A data report summarizing the field exploration and laboratory testing program, pumping test data analyses and results, as well as a preliminary assessment of dewatering options appropriate for the site was prepared for WSDOT.

2.0 INVESTIGATION METHODS

2.1 FIELD METHODS

2.1.1 DRILLING AND WELL CONSTRUCTION

Seven borings were drilled east of Shady Slope Road along US 2 for the groundwater study (Figure 2). One additional boring (SSSB3-01) was drilled west of Shady Slope Road for SR 395 geotechnical design purposes. The borings were drilled between March 26 and April 28, 2001 by Ruen Drilling, of Clark Fork, Idaho, using a truck-mounted, Mobile B-61 drill rig advancing 8-inch diameter hollow-stem augers. The borings extended to depths of up to 71 ft below ground surface (BGS). Soil samples were collected at minimum 5-ft intervals using a 2.0-inch, outside-diameter (OD), split-spoon sampler. The sampler was driven into the undisturbed soil ahead of the auger bit with a 140-pound drop hammer falling a distance of approximately 30 inches. The number of blows required to drive the sampler for each 6-inch interval of soil penetration, or part thereof, is noted on the boring logs next to the appropriate sampler notation. Soil samples were retrieved from the split spoon sampler and the lithology was described in accordance with WSDOT standards. The boring logs are presented in Appendix A. Following completion of drilling, several samples were selected for physical testing for grain size analysis, moisture content, and Atterberg limits. The physical testing data are presented in Appendix B.

Two-inch diameter piezometers were installed in six borings, and one 4-inch diameter extraction well was installed in one boring. The piezometers and the extraction well were constructed of schedule 40 PVC with 0.01-inch slotted screen. A filter pack of 10/20 Colorado silica sand was placed in the annular space around the screened portion of the wells to approximately 3 ft above the top of the screen. Bentonite chips were added above the filter sand to within approximately 2 ft of the ground surface. The piezometers and the extraction well were completed at the surface with 6-inch and 8-inch protective steel casing, respectively, with a lockable protective cap.

The hydrogeologic study piezometers and the extraction well were screened over intervals that were determined in the field based on the saturated conditions observed during drilling. Two piezometers were screened in an upper water-bearing zone over an interval of approximately 10 to 20 ft BGS, and three were screened across an intermediate zone over an interval of approximately 20 to 30 ft BGS. The extraction well was screened across the intermediate zone and a deeper saturated zone over an interval of approximately 20 to 40 ft BGS.

2.1.2 PUMPING TESTS

Pumping tests were conducted at the extraction well (US2-9-01) and at two piezometers (US2-4D-01 and US2-10-01) to collect data from each saturated zone. The pumping tests were conducted between May 1 and May 9, 2001, and included short-term step discharge tests, constant discharge pumping tests, and water level recovery tests. Prior to the beginning of each test, static water levels were measured in each monitored piezometer and in the pumped well.

The pumping tests were conducted using a submersible pump placed near the bottom of the extraction well. A discharge line extended from the pump to the surface, where a gate valve was used to regulate the pumping rate. A check valve was also present within the pump to prevent backflow after pump shutdown. At the surface, the discharge line extended approximately 200 ft away from the extraction well to a shallow ditch to promote flow of pumped water away from the test area. Pressure transducers connected to electronic data loggers were placed in the extraction well and in each observation well to measure water levels during each pumping test. Manual water level measurements were also collected using an electronic sounding tape. Barometric pressure was recorded with a transducer placed at ground surface near the observation wells. All data from the data loggers was downloaded onto a portable computer and backed up on a removable disk. Manual water level measurements collected throughout the test were recorded on field data sheets.

The step discharge pumping tests were conducted by pumping at different rates to estimate the maximum rate that could be maintained over the duration of the constant discharge test. At the completion of the test, the flow was adjusted to the target pumping rate for the constant discharge test, and the well was allowed to recover to 95% of its static level before the constant discharge tests were started.

The constant discharge tests were conducted at the target pumping rates for periods of approximately 5 to 9 hours, depending on the aquifer response observed during the test. The discharge rates were monitored at frequent intervals by measuring the time required to fill a graduated container of known volume. Adjustments were made to the gate valve in order to maintain a constant discharge rate throughout the test. Due to the low pumping rates [0.5 to 0.75 gallons per minute (gpm)], minor changes in the flow rate sometimes caused dramatic changes in the water levels in the pumped wells. Therefore, when flow adjustments were made, the time of the change was noted on the field form, and a measurement of the pumping rate was made to facilitate subsequent analysis. The response of each water-bearing zone was also monitored during each test in order to evaluate the degree of hydraulic communication between the different units.

Water level recovery was monitored in the extraction well and each monitoring well after the pump was turned off. The water levels were recorded until the levels reached 95 percent of their static pre-pumping water level.

2.1.3 WATER QUALITY ANALYSIS

One water sample was collected from piezometer US2-4D-01 on April 11, 2001 and analyzed for total cyanide using EPA method 335.2, and total fluoride using EPA method SM 413-AB to assess potential impacts from an aluminum facility located south of the project area. Water samples were also collected from piezometers US2-10-01 and US2-9-01 on May 1 and May 9, 2001 during the pumping tests and analyzed for the following constituents:

- Ammonia nitrogen by method SM4500NH3BC
- Total dissolved solids (TDS) by EPA method 1601.1
- Nitrate by EPA method 300.0
- Nitrite by EPA method 300.0
- Total kjeldahl nitrogen (TKN) by method SM 4500-Norg-B
- Total phosphorous by method SM 4500-P-B5D
- Total coliform and E-coli coliform by EPA Method CPRG-MUG

All samples were placed on ice in sealed containers and transported to Coffey Laboratories, Portland, Oregon, under a signed chain of custody. These analyses were conducted for WSDOT future use to assess the quality of water that may be routed away from the project area as part of a temporary or permanent dewatering system. The laboratory reports are presented in Appendix B.

2.2 PUMPING TEST ANALYTICAL METHODS

Analysis of pumping test data was conducted to obtain estimates of hydraulic conductivity and specific yield for each of the water-bearing zones. Field water level data were converted into drawdown and recovery data, which were analyzed using AQTESOLV (version 2.5), an aquifer test analysis software.

A variety of analytical methods are available with this software depending on the aquifer conditions encountered. For the pumping test data collected along US 2, the analytical methods of Neuman (1974) and Moench (1997) for unconfined aquifers were used. These methods account for the delayed water table response (delayed yield) that typically occurs in unconfined aquifers due to the actual

dewatering that occurs in the pore spaces of the aquifer material. Both of these methods make the following assumptions:

- The aquifer is unconfined and has seemingly infinite areal extent over the area influenced by the test.
- The aquifer is homogeneous, isotropic, and of uniform thickness.
- Flow is unsteady.

The method used by Neuman assumes the diameter of the extraction well is small so that storage in the well can be neglected, while the method of Moench accounts for well storage effects. The above assumptions represent ideal conditions, which are rarely, if ever, met in the field. However, these analytical solutions provide reasonable analytical models for estimating aquifer hydraulic parameters within an order of magnitude.

Water level recovery data was also analyzed separately using the recovery method developed by Theis (1935) as modified by Neuman (1975). This method is applicable to unconfined aquifers, and was applied to late time recovery data.

3.0 FINDINGS AND RESULTS

The following sections provide a brief summary of regional geology, a description of geologic conditions encountered in the project area, and presents the results of pumping test analyses and seepage calculations.

3.1 REGIONAL GEOLOGY

Regional geology in the project area include, from oldest to youngest: metamorphic and igneous rocks, the Latah Formation and Columbia River Basalt Group (CRBG), Lake Missoula catastrophic flood deposits, and eolian deposits.

The metamorphic basement rock includes the Spokane dome of the Priest River metamorphic core complex, which are intruded by Cretaceous and early Tertiary granite rocks (Boleneus and Derkey 1996).

Miocene basalt flows occupy the lower valleys and foothills and abut the higher mountains in the project area. Two formations of the CRBG, the Wanapum Basalt (Priest Rapid Member) and the Grande Ronde Basalt, have been mapped in the project area (Derkey 1997; Derkey, Gerstel, and Logan 1998) with a thickness of 50 to 150 ft (Griggs 1973). The earlier basalt flows likely blocked stream/river drainages, forming either a series of lakes or a single large basin along the north and east rim of the basalt field. Lacustrine sediments, derived from erosion of the older basalts and the pre-Tertiary rocks in the region, were deposited in the basin. These sediments, consisting primarily of silt and clay, with minor sand and gravel, form the Latah Formation. The Latah Formation is generally described as poorly indurated siltstone, claystone, sandstone, and minor conglomerate, containing scattered volcanic ash layers. Within the project area, the Latah Formation is overlain by Wanapum Basalt and has limited exposures on the hillsides northwest of US 2.

Quaternary deposits include melt water deposits from ice sheets consisting chiefly of sand and gravel with silt and clay deposited in and along the valleys of the Spokane and Little Spokane Rivers. In addition, proglacial lake sediments exist in tributary valleys such as the Peone Prairie northeast of Spokane (east of the project area). The glacial lake deposits consist predominantly of sand, silt, and clay with scattered drop stones.

Flood deposits from Lake Missoula flood waters inundated the Spokane area to a maximum elevation of 2,700 ft (Derkey 1997). These flood events likely swept down the Spokane and Little Spokane River valleys scouring deposits of previous flood events, cutting new channels into the pre-Pleistocene bedrock, and leaving behind new deposits of boulders, cobbles, gravel, and sand. In less

energetic environments, slack water deposits of chiefly sand and lacustrine sediments were laid down. The maximum thickness of the flood deposits in the Little Spokane River Valley are on the order of 500 ft (Derkey 1997).

Surficial deposits of wind-blown sand (Holocene and Pleistocene Epoch) are present over the flood deposits south of the project area, south of Farwell Road. The wind-blown deposits are derived primarily from Pleistocene flood deposits that mantle much of the project area.

3.2 PROJECT GEOLOGY

Seven borings were drilled along US 2 between Shady Slope Road and Deadman Creek at the locations shown on Figure 2 for this hydrogeologic study. These borings generally encountered deposits of silty fine sand and fine to medium sand separated by lenses of interbedded silt and clayey silt to depths of 30 to 40 ft BGS. In two borings (US2-9-01 and US2-4D-01) these sands and interbedded clays were underlain by a layer of hard clayey silt (Latah Formation) at depths of approximately 35 to 65 ft BGS [elevation 1,770 to 1,795 ft above mean sea level (MSL)]. Three borings (US2-7-01, US2-6-01 and US2-4D-01) also encountered basalt bedrock at depths of approximately 40 to 56 ft BGS (elevation 1,775 to 1,800 ft above MSL).

Cross sections showing the project area geology are presented on Figures 3 and 4. The location and orientation of the cross section lines are shown on Figure 2. Borings from other sections of the SR395 project (Landau Associates 2001a and 2001b) were also used to develop an understanding of the project geology.

The sand deposits are interpreted as Pleistocene flood deposits, and consist of medium dense to dense, homogeneous, well graded to poorly graded, fine to medium sand with varying amounts of silt. The sand was typically light grayish-brown to brown in color, with subangular to rounded grains.

Interfingering with the Pleistocene flood deposits are interbedded, fine-grained deposits of stiff to very stiff, fat and lean clay; and medium dense elastic silt and sandy silt; over and interbedded with deposits of medium dense, silty fine sand. The silt and clay deposits observed in the borings were variable in thickness, but generally consisted of two units that ranged between 0.5 and 8 ft thick depending on the unit and location. A third silt and clay unit was present south of the project area.

The interbedded sand, silt, and clay deposits were underlain at three locations (US2-5-01, US2-4D-01, US2-9-01) by a very stiff to very hard elastic silt and very dense clayey sand (Latah Formation) that ranged between 6 and 23 ft thick. This silt and clay was described as homogeneous, laminated, and blocky, reddish to yellowish brown, and moist. The sand was clayey, moist, very dense, and poorly graded, with homogeneous structure, and a reddish brown color. This unit was overlying basalt bedrock at US2-4D-01 at a depth of approximately 57 ft BGS (elevation 1,774 ft).

3.3 PROJECT HYDROGEOLOGY

Groundwater was intercepted in vertically discontinuous zones at several different elevations. Groundwater occurrence is controlled, in part, by the presence of silt and clay layers. These low permeability layers cause groundwater to accumulate or perch above them.

Perched groundwater was observed on the clay and silt units present in all borings except US2-7-01. Three individual perched zones were identified: a shallow zone (unit #1) with a typical depth to water of approximately 8 to 12 ft BGS, an intermediate zone (unit #2) with a depth to water of approximately 25 ft BGS, and a deeper zone (unit #3) with a depth to water of approximately 37 ft BGS. Five piezometers were installed to monitor groundwater along US 2: two in the shallow zone (US2-10-01 and US2-4S-01) and three in the intermediate zone (US2-4D-01, US2-5-01, and US2-6-01). One extraction well was installed in the deep zone (US2-9-01). Well construction details for the piezometers and the extraction well are presented in Table 1, and measured groundwater elevations at each location are presented in Table 2.

The saturated thickness of each water-bearing zones at these locations was approximately 7, 5, and 5 ft for the shallow, intermediate, and deep zones, respectively. Based on the lithology observed in the borings, observed groundwater conditions, and a review of drilling logs for the area on file with Ecology, the lateral extent of the perched groundwater zones was difficult to estimate due to the discontinuous nature of the silts and clays in the area; however, the potential exists for shallow groundwater to be present throughout the area surrounding the proposed SR 395/US 2 interchange. As shown on the two cross-sections (Figures 3 and 4) these discontinuous water-bearing zones have the potential to communicate with one another and provide recharge to units that may be exposed during construction at US 2.

3.4 PUMPING TESTS RESULTS

Three pumping tests were conducted to gather data from each of the three water-bearing zones encountered in the vicinity of the project site. These tests were conducted at well US2-9-01 for the deep zone, at US2-4D-01 for the intermediate water-bearing zone, and at well US2-10-01 for the shallow water-bearing zone. Each test was conducted in general accordance with the procedures outlined in Section 2. Table 3 summarizes general information about each test, and plots of drawdown versus time for each test are presented on Figures C-1, C-2, and C-3 in Appendix C. A summary of each pumping test is presented below.

3.4.1 WELL US2-9-01

Well US2-9-01 was pumped on May 1, 2001 from the deep water-bearing zone (unit #3) at a rate of approximately 0.8 gpm for a period of 8½ hours. Drawdown in the extraction well after 8 hours was approximately 1 foot. No response was seen in any of the observation wells. Drawdown in the extraction well reached 95 percent of its maximum drawdown within 30 minutes of the start of pumping, and water levels in the extraction well recovered to 95 percent of their static level within 30 minutes of the pump being turned off.

Due to the small amount of drawdown observed during the pumping test at US2-9-01, one additional constant discharge test was conducted on May 2, 2001. This test was conducted at a pumping rate of 1.2 gpm and continued for approximately 2½ hours before the well began to dewater. The water level in the extraction well recovered to 95 percent of its static pre-pumping level within 30 minutes of pump shut off.

3.4.2 WELL US2-4D-01

Well US2-4D-01 was pumped on May 7, 2001 from the intermediate water-bearing zone at a rate of approximately 0.45 gpm for a period of 6 hours. Drawdown in the pumping well after 6 hours was approximately 10.5 ft. This drawdown exceeded the saturated thickness of the 5 ft thick water-bearing zone because the pump was placed in a well sump below the bottom of the saturated zone. A drawdown response of approximately 0.1 ft was observed in the same zone at well US2-6-01, 100 ft away, and no response was observed in the lower saturated zone at well US2-9-01, or in the shallow water-bearing zone at wells US2-4S-01 and US2-10-01. A temporary rise of 0.15 ft was observed in the water table at US2-5-01, but this is not interpreted to be related to pumping at US2-4D-01. Drawdown in the extraction well reached 9 ft, or 85 percent of its maximum drawdown within 90 minutes of the start of pumping, and was relatively stable thereafter. The water level in the extraction well recovered to 95 percent of its static levels within 30 minutes of pump shut off.

3.4.3 WELL US2-10-01

Well US2-10-01 was pumped on May 9, 2001 from the shallow water-bearing zone at a rate that ranged from 0.45 to 0.55 gpm for a period of 5.5 hours. The maximum observed drawdown in the pumping well was approximately 7.5 ft. Drawdown in well US2-4S-01, approximately 30 ft away, was approximately 0.1 ft. No response was measured in wells screened in the intermediate or lower water-bearing zones (US2-4D-01 and US2-9-01, respectively). Drawdown in the extraction well reached 7.5 ft

after 3½ hours before the pumping rate was adjusted to prevent dewatering. Water level recovered to 95 percent of its static water level in less than 30 minutes of pump shut off.

3.5 PUMPING TEST ANALYSES

Pumping test data were analyzed using the methods described in Section 2. Due to the very limited response measured in observation wells during each pumping test, no analysis was performed on the observation well data.

The results of the pumping test analyses are presented in Table 4. The values of hydraulic conductivity and specific yield are presented as a range of values based on the results from the different analytical methods. Values of hydraulic conductivity ranged from 1 to 16 ft/day in the shallow saturated zone, from 0.5 to 5 ft/day in the intermediate zone, and from 5 to 25 ft/day in the deep zone. These values are consistent with literature values for fine sand and silty fine sand, and are consistent with visual observations made during drilling.

Values of specific yield ranged between 10^{-2} and 10^{-5} , which are lower than typical values for unconfined aquifers. Expected specific yield should range between 0.01 and 0.3 (Freeze and Cherry 1979). Drawdown data collected from the pumping wells is not considered as reliable for estimating specific yield as data collected from observation wells due to delayed yield of the dewatered portion of the aquifer, heterogeneous lithology, and well inefficiency that occurs in the pumping well. Therefore, values smaller than 10^{-2} are not considered to be reasonable.

3.6 SEEPAGE CALCULATIONS

The rate at which water will enter an excavation face will be a function of the hydraulic properties of the water-bearing material, the saturated thickness, and the amount of recharge available to the water-bearing strata. The saturated thickness was estimated based on the geologic information gathered during the field exploration and on water level measurements made in the piezometers (see Table 2). The hydraulic properties of the saturated material were based on analysis of data collected from the pumping tests conducted at wells screened within each zone. It was assumed that for the proposed cut depth profile (shown on Figure 4), only the two upper water-bearing zones would contribute water to the excavation.

Estimates of seepage rates were made using the Dupuit-Forcheimer formula for phreatic aquifers. This equation describes the rate of discharge (Q) from a seepage face (per unit width normal to flow) as a function of the hydraulic conductivity (K) of the saturated material, the height (h) of the water table, and the distance (L) from the seepage face to a point where the height of the water table is not affected by the discharge (Bear 1987). This equation is:

$$Q = K(h_0^2 - h_L^2)/2L$$

where

K = hydraulic conductivity (L/T)

h_0 = the static height of the water table (L)

h_L = height of the water table at the seepage face (L)

L = distance from the seepage face to where $h = h_0$ (L)

This formula assumes the slope of the water table surface is small, and that flow to the seepage face is essentially horizontal. For the purpose of this calculation, the following values were used to describe conditions along US 2:

L = 15ft. This value is based on the very small drawdowns (if any) recorded in the observation wells during the pumping tests, and represents a conservative estimate of the influence of a potential seepage face on the water table in the area.

h_0 = 7 ft (for the upper water-bearing zone), **and 5 ft** (for the intermediate water-bearing zones). These values are the saturated thicknesses, and are based on geological and water level data collected during the field investigation.

h_L = 0.5 ft. This value was used to represent the height of the water table at the seepage face. It was assumed that the water table would not decline completely to the base of the saturated zone.

K = 0.5 – 16 ft/day. These values are from the analysis of the pumping test data. Although the two upper saturated zones appeared to behave independently during the pumping tests, a conservative range of hydraulic conductivity that represents both water-bearing zones was used to calculate seepage flow for each zone intersecting the trench.

Estimated values of seepage discharge per unit length of trench are presented in Table 5 for the upper and intermediate water-bearing zones using the parameters and assumptions described above. The estimated range of discharge entering both sides of an excavation from the two saturated zones is 0.006 to 0.204 gpm per foot of trench. This calculation is based on the assumption that the hydrogeologic conditions do not vary away from, or along, the exposed area of the cut, and that water enters the trench at the same rate from both sides of the trench. The estimated seepage rates do not include a time of

duration, and are based on the assumption that infinite recharge is available to the exposed units. Should any of these conditions change, the estimated rate of flow into a cut would also change.

3.7 WATER QUALITY RESULTS

Potential impacts to groundwater quality from the Kaiser Mead aluminum facility located approximately 1½ miles south of the US 2 study area were reviewed with Ecology personnel. Based on this review (Skylingstand, P., March 15, 2001, personal communication) groundwater impacted with fluoride and cyanide extends to the northwest from the facility, and does not appear to have the potential to impact the area around the proposed SR395/US 2 interchange.

Water quality samples were collected from wells US2-9-01, US2-10-01 and US2-4D-01 and analyzed for the parameters specified in Section 2. Results of the laboratory analyses are presented in Table 6, and laboratory reports are presented in Appendix B.

The analytical results of the cyanide and fluoride samples collected from US2-4D-01 indicated that cyanide was not detected at or above the method reporting level, and fluoride was detected at 0.6 milligrams per liter (mg/l). These results concur with the review of Ecology files, which suggested that cyanide and fluoride impacted groundwater would most likely not be encountered in the immediate vicinity of the project study area. Concentrations of nitrate were reported at concentrations of 9.2 mg/l and 1.4 mg/l in US2-9-01 and US2-10-01, respectively. Concentrations of TDS were reported at 340 mg/l and 150 mg/l in US2-9-01 and US2-10-01, respectively. Results for total coliform were absent at US2-9-01, and were present at US2-10-01. Concentrations of ammonia, nitrite, TKN, E-coli coliform, and total phosphorus were not reported at or above the method reporting level.

Water routed away from the site as part of a permanent or temporary dewatering system may be regulated by the State depending on how the water is ultimately discharged, whether to the ground surface (and hence to groundwater) through a constructed bioswale or similar alternative, or whether it is discharged directly to a surface water body, such as Deadman Creek.

Water discharged to groundwater would be regulated by the Groundwater Quality Standards, WAC 173-200. Discharges to Deadman Creek would be regulated by the Water Quality Standards For Surface Waters of the State of Washington under WAC 173-201A. Values of nitrate and TDS from the samples collected were below the groundwater quality standards of 10 mg/l and 500 mg/l, respectively. Discharge criteria to a surface water body such as Deadman Creek will depend on the classification of the Creek with respect to present and potential water uses, the natural background water quality of the Creek, and the impacts of potential discharges on the aquatic community and beneficial uses of the water.

4.0 SUMMARY AND CONCLUSIONS

Field explorations were conducted along US 2 to investigate the presence of shallow groundwater in the vicinity of the proposed SR 395/US 2 interchange. This investigation found that the area is underlain by interbedded sands, silts and clays with perched groundwater. Groundwater that may impact highway construction within the study area occurred primarily within two perched zones, with water levels at approximately 9 and 22 ft BGS (elevation 1825 and 1810 ft MSL). A third deeper zone also contained water at a depth of approximately 37 ft BGS (elevation 1796 ft MSL). Pumping tests indicated that the three water-bearing zones were independent of each other at the location of the tests. Hydraulic conductivities ranged between 0.5 and 16 ft/day for the two upper zones.

Based on the proposed cut depths for US 2 construction provided by WSDOT, the potential exists for shallow groundwater from the two upper units to emerge as seepage into cuts excavated during construction. This seepage will likely occur at the cut face where the two upper units intersect the excavation, and may also occur through the base of the excavation where the cut extends across the saturated interval. The deeper water-bearing zone (unit #3) appears to be below the proposed cut depth.

Estimated seepage discharge per unit length of trench for the combined upper and intermediate water-bearing zones range from 0.006 to 0.204 gpm per foot of trench. If a total length of 7,500 ft of water-bearing strata is exposed in the cut at one time (5,000 ft total from two sides of the trench intersecting the upper zone, and 2,500 ft total from two sides of the trench intersecting the intermediate zone), estimated seepage quantities could range between 25 to 900 gpm. Therefore, both temporary and permanent dewatering measures would be necessary to control seepage and route water away from the sides and base of the excavation. Due to the discontinuous nature of the water-bearing strata, there is potential that the water-bearing units may be dewatered over time and the flows will decrease; however, conclusive evidence of this process was not obtained during this study.

Temporary control of seepage would be necessary to limit water accumulating in the excavation and control stability of the cut face. During construction this may be accomplished by phasing the cuts to allow natural dewatering in advance of construction activities, sloping cuts to ensure stability, the use of armoring and geotextiles to prevent piping and increase slope stability, or installation of shallow drains or well points to lower the water table near the excavation.

Permanent measures would also be necessary to convey water away from the subgrade. These measures may include blanket drains or marginal drains with a permanent gravel sub-base drainage layer beneath the roadway section. Conveyance of water could be accomplished through gravity drainage to

the east along US 2 towards Deadman Creek, where it could be infiltrated through a constructed bioswale or discharged directly to the creek, depending on permitting requirements and groundwater quality.

5.0 USE OF THIS REPORT

This hydrogeological report was prepared for the exclusive use of WSDOT for specific application to the US 2 groundwater study project. The use by others, or for purposes other than intended, is at the user's sole risk. The findings, recommendations, and opinions presented herein are based on review of readily available hydrogeologic and geologic information, field explorations and testing, and our understanding of the project requirements. Within the limitations of scope, schedule, and budget, information presented in this data report were prepared in accordance with generally accepted professional practices in this area at the time this document was prepared. We make no other warranty, either express or implied.

We appreciate the opportunity to provide these services to WSDOT and look forward to providing further assistance on this project. Please contact either Tom Briggs or Craig Schwyn at 509-327-9737 if you have any questions regarding the information contained in this data report.

LANDAU ASSOCIATES, INC.

By:



Thomas D. Briggs
Senior Project Hydrogeologist

and



Craig C. Schwyn, R.G.
Associate Hydrogeologist

Reviewed By:

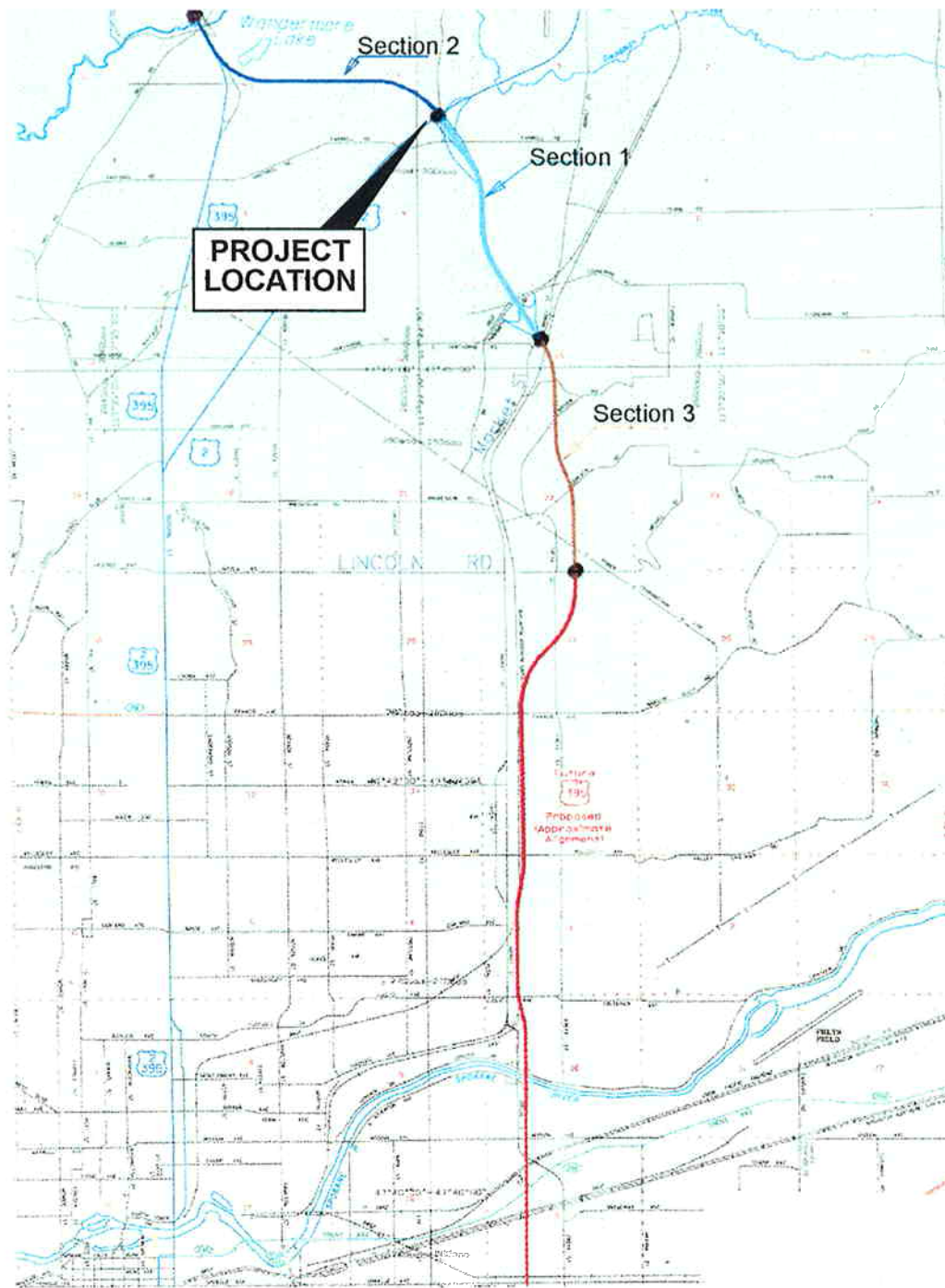


Dennis R. Stettler, P.E.
Principal

TDB/CCS/DRS/djn
No. 244009.010

6.0 REFERENCES

- Bear, Jacob and Arnold Verruijt. 1987. *Modeling Groundwater Flow and Pollution*. Published by D. Reidel Publishing Company.
- Boleneus, D.E. and R.E. Derkey. 1996. *Geohydrology of the Peone Prairie, Spokane County, Washington*. Washington Geologist. Vol. 24. No. 1. March 1996.
- Derkey, R.E. 1997. *Geologic Map of the Mead 7.5 Minute Quadrangle, Spokane County, Washington*. Washington Division of Geology and Earth Resources Open File Report 97-3. June 1997.
- Derkey, R.E., W.J. Gerstel, and R.L. Logan. 1998. *Geologic Map of the Dartford 7.5 Minute Quadrangle, Spokane County, Washington*. Washington Division of Geology and Earth Resources Open File Report 98-6. June 1998.
- Freeze, R. Allan and John A. Cherry. 1979. *Groundwater*. Published by Prentice-Hall, Inc., Englewood Cliffs N.J. 07632.
- Griggs. 1973. *Geologic Map of the Spokane Quadrangle, Washington, Idaho, and Montana*. U.S. Geological Survey Miscellaneous Geological Investigations Map I-768.
- Landau Associates. 2001a. *Geotechnical Data Report, SR 395-North Spokane Corridor, Section 1-Hawthorne Road to US 2, Spokane, WA*. February.
- Landau Associates. 2001b. *Geotechnical Data Report, SR 395-North Spokane Corridor, Section 2-From US2 to SR395, Spokane, WA*. March.
- Moench, A.F. 1997. *Flow to well of finite diameter in a homogenous, anisotropic water table aquifer*. Water Resources Research, vol. 33, no. 6, pp. 1397-1407.
- Neuman, S.P. 1974. *Effect of partial penetration on flow in unconfined aquifers considering delayed gravity response*. Water Resources Research, vol. 10, no. 2, pp. 303-312.
- Skyllingstand, P. March 15, 2001. Personal communication (conversation with Tom Briggs, Landau Associates, Spokane, WA). State of Washington Department of Ecology, Eastern Region, Spokane, WA.
- Theis, C.V. 1935. *The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage*. Am. Geophys. Union Trans., 16:519-524.



No Scale

Base drawing provided by WSDOT

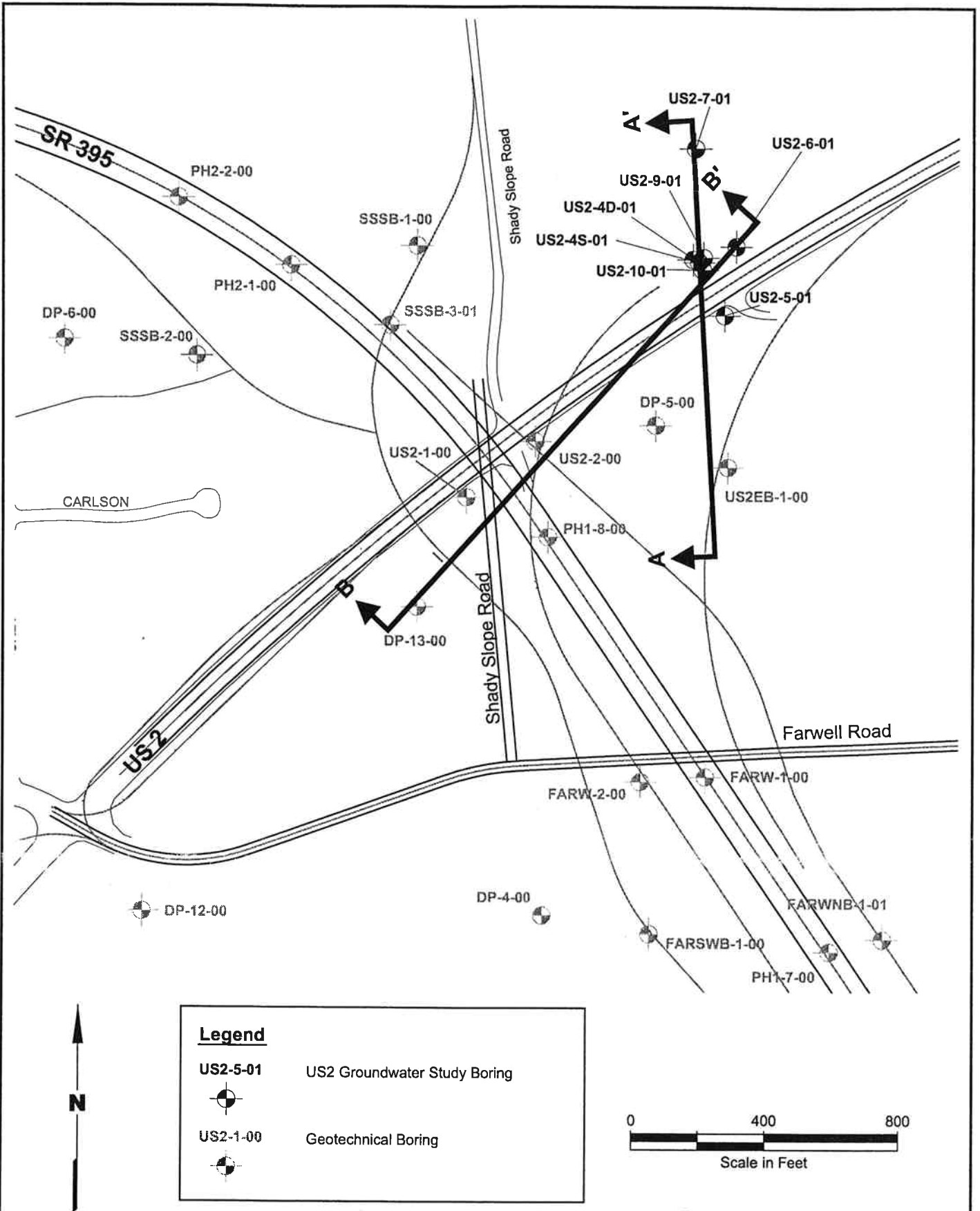


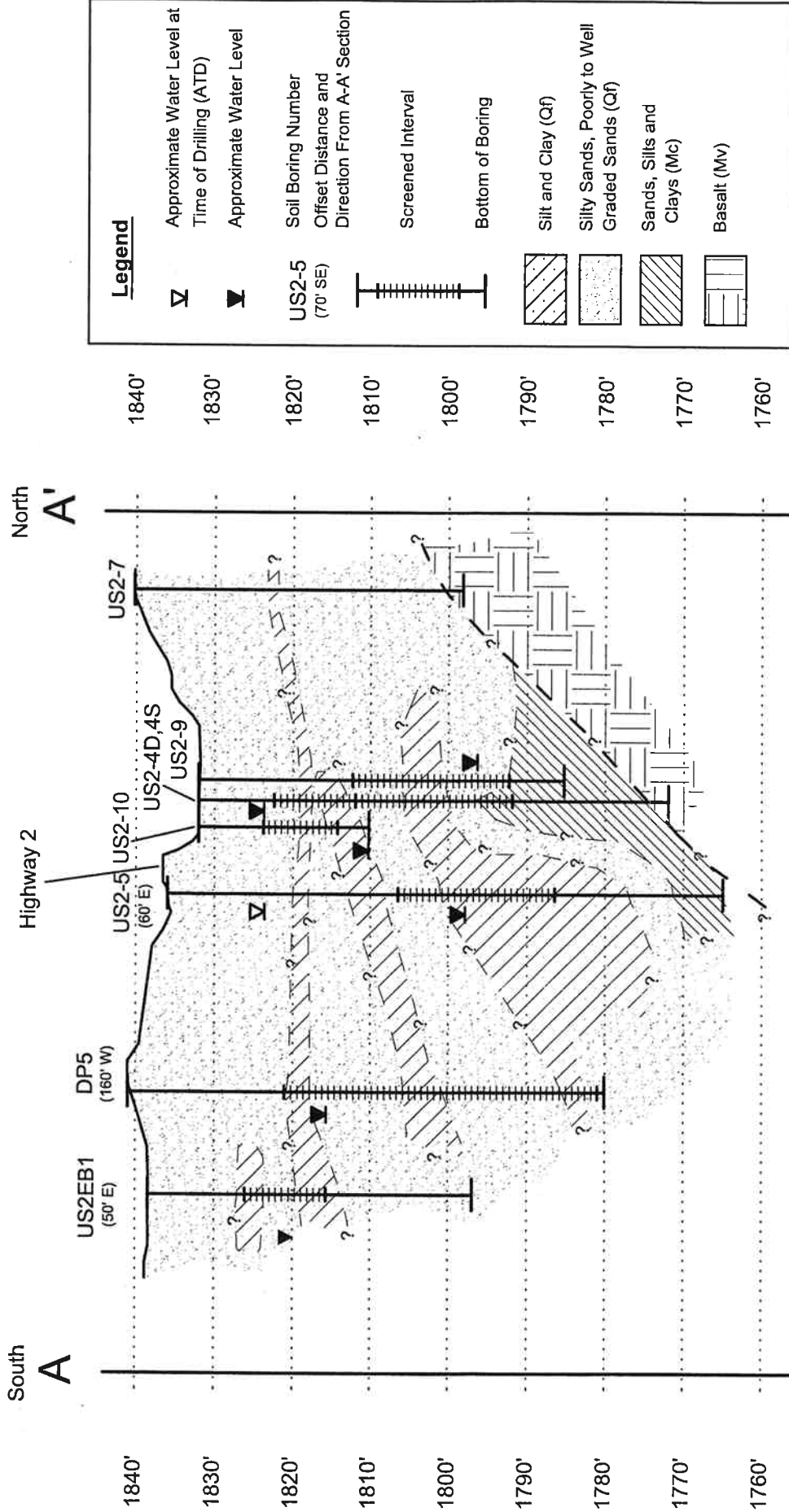
WSDOT SR 395 North Spokane
Corridor Project
Spokane, Washington

Vicinity Map

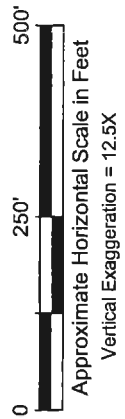
Figure
1

US2 Groundwater Study I:\cad\pjt-file\244009\10\area2 (A) 6/2001





NOTE: Soil and rock descriptions are generalized based on field interpretations and laboratory data. Stratigraphic contacts are interpreted between borings. Actual contacts may vary.



SR 395 North Spokane
Corridor Project
Spokane, Washington

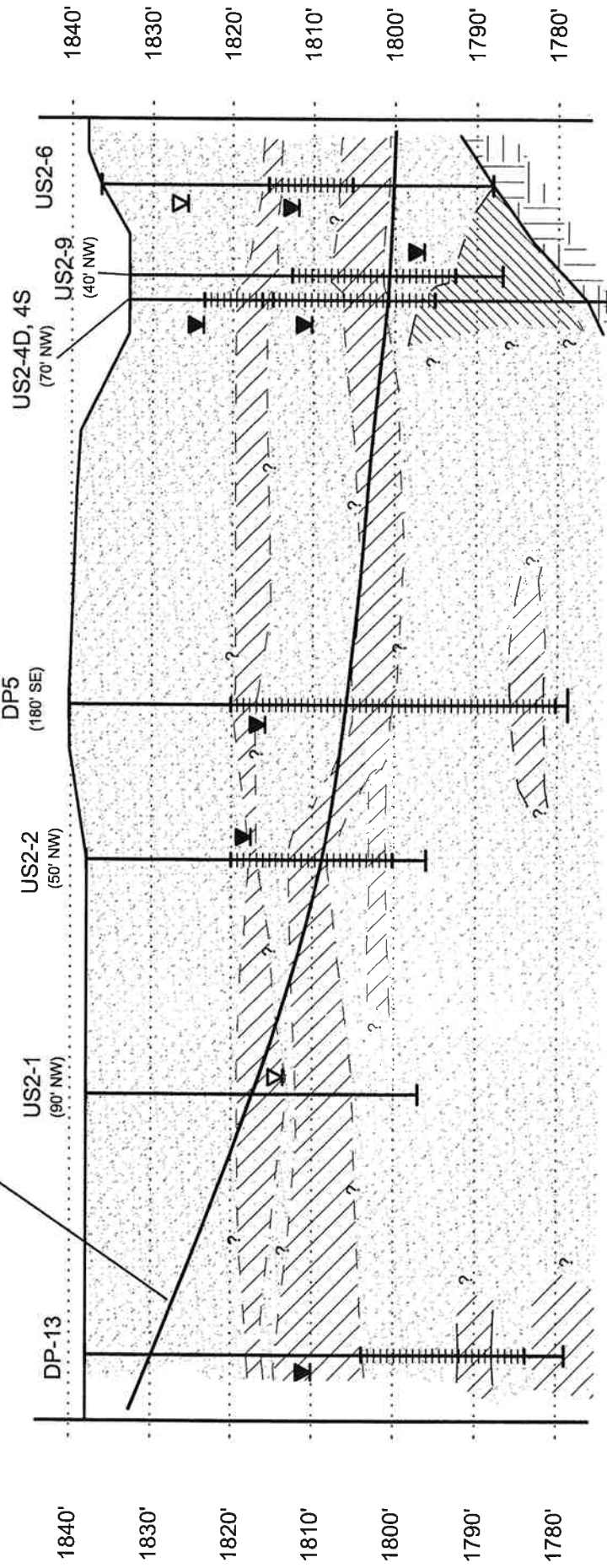
Cross Section A - A'

Figure
3

South West Proposed Cut Depth North East

B

B'



Approximate Water Level at Time of Drilling (ATD)
 Approximate Water Level
 Soil Boring Number
 Offset Distance and Direction From B-B' Section
 Screened Interval
 Bottom of Boring

Legend

- Silt and Clay (Qf)
- Silty Sand, Poorly to Well Graded Sands (Qf)
- Sands, Silts and Clays (Mc)
- Basalt (Mv)



SR 395 North Spokane
 Corridor Project
 Spokane, Washington

Cross Section B - B'

Figure 4

TABLE 1
BORING AND WELL CONSTRUCTION DETAILS
US2 GROUNDWATER STUDY
S.R. 395 NORTH SPOKANE CORRIDOR PROJECT

| Well | Installation Date | Boring Depth (ft BGS) | Well Diameter (inches) | Wellhead Elevation (ft-MSL) | | Total Depth of Well (ft-BGS) | Approximate Depth to Water (ft-BGS) | Approximate Groundwater Elevation (ft-MSL) |
|--------------------------|-------------------|-----------------------|------------------------|-----------------------------|------------|------------------------------|-------------------------------------|--|
| | | | | Ground Surface | Top of PVC | | | |
| Shallow Zone | | | | | | | | |
| US2-4S-01 | 04/02/2001 | 21.5 | 2 | 1833.0 | 1835.8 | 19.5 | 9.2 | 1823.8 |
| US2-10-01 | 04/26/2001 | 21.5 | 2 | 1832.6 | 1834.6 | 17.4 | 8.7 | 1823.9 |
| Intermediate Zone | | | | | | | | |
| US2-4D-01 | 03/28/2001 | 59.5 | 2 | 1833.3 | 1835.4 | 40.0 | 23.1 | 1810.2 |
| US2-5-01 | 03/30/2001 | 71.5 | 2 | 1836.5 | 1839.2 | 50.0 | 38.6 | 1797.9 |
| US2-6-01 | 04/04/2001 | 49.0 | 2 | 1836.0 | 1838.6 | 32.0 | 24.1 | 1811.9 |
| Deep Zone | | | | | | | | |
| US2-9-01 | 04/26/2001 | 47.0 | 4 | 1832.8 | 1835.7 | 46.0 | 36.2 | 1796.6 |

Notes:

ft BGS = feet below ground surface.

ft MSL = feet above mean sea level.

TABLE 2
GROUNDWATER ELEVATION SUMMARY
US2 GROUNDWATER STUDY
S.R. 395 NORTH SPOKANE CORRIDOR PROJECT

| Well | Date Measured | Well Elevation (ft-MSL) | Depth to Water (ft-BTOC) | Groundwater Elevation (ft-MSL) |
|--------------|---------------|----------------------------|-----------------------------|-----------------------------------|
| Shallow | | | | |
| US2-4S-01 | 04/11/2001 | 1835.80 | 12.00 | 1823.80 |
| | 04/26/2001 | | 12.03 | 1823.77 |
| | 05/01/2001 | | 11.94 | 1823.86 |
| | 05/07/2001 | | 11.91 | 1823.89 |
| | 05/08/2001 | | 11.90 | 1823.90 |
| US2-10-01 | 04/26/2001 | 1834.60 | 10.66 | 1823.94 |
| | 05/01/2001 | | 10.60 | 1824.00 |
| | 05/08/2001 | | 10.55 | 1824.05 |
| Intermediate | | | | |
| US2-4D-01 | 04/11/2001 | 1835.40 | 24.05 | 1811.35 |
| | 04/26/2001 | | 25.21 | 1810.19 |
| | 05/01/2001 | | 25.48 | 1809.92 |
| | 05/07/2001 | | 25.68 | 1809.72 |
| | 05/08/2001 | | 25.92 | |
| US2-5-01 | 04/11/2001 | 1839.20 | 36.54 | 1802.66 |
| | 04/26/2001 | | 33.62 | 1805.58 |
| | 05/01/2001 | | 42.67 | 1796.53 |
| | 05/07/2001 | | 41.12 | 1798.08 |
| | 05/08/2001 | | 41.51 | 1797.69 |
| US2-6-01 | 04/11/2001 | 1838.60 | 26.39 | 1812.21 |
| | 04/26/2001 | | 26.73 | 1811.87 |
| | 05/01/2001 | | 26.89 | 1811.71 |
| | 05/07/2001 | | 27.00 | 1811.60 |
| | 05/08/2001 | | 26.96 | 1811.64 |
| Deep | | | | |
| US2-9-01 | 04/26/2001 | 1835.70 | 28.53 | 1807.17 |
| | 05/01/2001 | | 39.95 | 1795.75 |
| | 05/07/2001 | | 39.18 | 1796.52 |
| | 05/08/2001 | | 39.08 | 1796.62 |
| Other | | | | |
| PH1-8-00 | 04/11/2001 | 1839.10 | 25.87 | 1813.23 |
| US2EB-1-00 | 04/11/2001 | 1838.20 | 19.68 | 1818.52 |
| DP-5-00 | 04/11/2001 | 1844.30 | 27.46 | 1816.84 |
| DP-13-00 | 04/11/2001 | 1843.40 | 33.67 | 1809.73 |

Notes:

ft BTOC = feet below top of casing.
ft MSL = feet above mean sea level.

TABLE 3
PUMPING TEST SUMMARY
US2 GROUNDWATER STUDY
S.R. 395 NORTH SPOKANE CORRIDOR PROJECT

1 of 1

| Extraction Well | Pumped Unit | Pumping Rate (gpm) | Observation Wells | Screened Unit | Horizontal Distance From Extraction Well (ft) | Observation Well Response |
|-----------------|-------------|--------------------|-------------------|---------------|---|---------------------------|
| US2-10-01 | 1 | 0.45 - 0.55 | US2-4S-01 | 1 | 30 | Drawdown = 0.1 ft |
| | | | US2-4D-01 | 2 | 20 | No response |
| | | | US2-9-01 | 3 | 30 | No response |
| US2-4D-01 | 2 | 0.45 | US2-6-01 | 2 | 130 | Drawdown = 0.1 ft |
| | | | US2-5-01 | 2 | 175 | No response |
| | | | US2-9-01 | 3 | 30 | No response |
| | | | US2-4S-01 | 1 | 20 | No response |
| US2-9-01 | 3 | 0.8 | US2-4D-01 | 2 | 30 | No response |
| | | | US2-6-01 | 2 | 100 | No response |
| | | | US2-5-01 | 2 | 175 | No response |
| | | | US2-4S-01 | 1 | 30 | No response |
| US2-9-01 | 3 | 1.2 | US2-4D-01 | 2 | 30 | No response |
| | | | US2-6-01 | 2 | 100 | No response |

Notes:

ft = feet.

gpm = gallons per minute.

Unit 1 = shallow saturated interval.

Unit 2 = intermediate saturated interval.

Unit 3 = deep saturated interval.

TABLE 4
PUMPING TEST RESULTS
US2 GROUNDWATER STUDY
S.R. 395 NORTH SPOKANE CORRIDOR PROJECT

1 of 1

| Unit | Extraction Well | Pumping Rate (gpm) | Test Duration (hrs) | Observed Drawdown (ft) | Saturated Thickness (ft) | Hydraulic Conductivity (ft/day) | Specific Yield |
|-------------------|-----------------|--------------------|---------------------|------------------------|--------------------------|---------------------------------|------------------------|
| Shallow (#1) | US2-10-01 | 0.45 - 0.55 | 5.5 | 7 | 7 | 1 - 16 | 10^{-2} to 10^{-4} |
| Intermediate (#2) | US2-4D-01 | 0.45 | 6 | 11* | 5 | 0.5 - 5 | 10^{-5} to 10^{-3} |
| Deep (#3) | US2-9-01 | 0.8 1.2 | 8.5 2.5 | 1 Well dewatered | 5 | 5 - 25 | 10^{-3} to 10^{-2} |

Notes:

ft = feet.

gpm = gallons per minute.

hrs = hours.

* Pump set below bottom of saturated zone.

TABLE 5
ESTIMATED SEEPAGE RATES
US2 GROUNDWATER STUDY
S.R. 395 NORTH SPOKANE CORRIDOR PROJECT

| Unit | Hydraulic Conductivity (ft/day) | Saturated Thickness (ft) | L (ft) | h_0 (ft) | h_L (ft) | Q (gpm/ft of trench) |
|-------------------|---------------------------------|--------------------------|--------|------------|------------|----------------------|
| Shallow (#1) | 0.5 | 7 | 15 | 0.5 | 7 | 0.004 |
| | 16 | 7 | 15 | 0.5 | 7 | 0.135 |
| Intermediate (#2) | 0.5 | 5 | 15 | 0.5 | 5 | 0.002 |
| | 16 | 5 | 15 | 0.5 | 5 | 0.069 |
| Estimated Minimum | | | | | | 0.006 |
| Estimated Maximum | | | | | | 0.204 |

Notes

ft = feet.

gpm = gallons per minute.

h_L = the height of the water table at the seepage face.

h_0 = the static height of the water table.

K = hydraulic conductivity.

L = distance from seepage face where $h = h_0$.

$Q = K(h_L^2 - h_0^2)/2L$ (Bear 1987).

TABLE 6
WATER QUALITY TESTING ANALYTICAL RESULTS
US2 GROUNDWATER STUDY
S.R. 395 NORTH SPOKANE CORRIDOR PROJECT

1 of 1

| Analysis | Method | Units | Sample Location | | |
|----------------------------|----------------|---------|-----------------|----------|-----------|
| | | | US2-4D-01 | US2-9-01 | US2-10-01 |
| Conventional Parameters | | | | | |
| Total Cyanide | EPA 335.2 | mg/l | 0.01 U | NA | NA |
| Total Fluoride | SM 413-AB | mg/l | 0.6 | NA | NA |
| Ammonia Nitrogen | SM4500NH3BC | mg/l | NA | 0.2 U | 0.2 U |
| Total Dissolved Solids | EPA 1601.1 | mg/l | NA | 340 | 150 |
| Nitrate | EPA 300.0 | mg/l | NA | 9.2 | 1.4 |
| Nitrite | EPA 300.0 | mg/l | NA | 0.2 U | 0.2 U |
| Total Kjeldahl Nitrogen | SM 4500-Norg-B | mg/l | NA | 0.2 U | 0.2 U |
| Total Phosphorus | SM 4500-P-B5D | mg/l | NA | 0.05 U | 0.1 U |
| Microbiological Parameters | | | | | |
| E. coli | EPA CPRG-MUG | /100 ml | NA | Absent | Absent |
| Total Coliform | EPA CPRG-MUG | /100 ml | NA | Absent | Present |

Notes:

NA = not analyzed.

U = indicates compound was analyzed for, but was not detected at the given detection limit.

Sample collected from US2-4D-01 labeled as US2GW.

APPENDIX A

Boring Logs



Test Boring Legend

| Sampler Symbols | |
|-----------------|--|
| | Standard Penetration Test |
| | Oversized Penetration Test (Dames & Moore, California) |
| | Shelby Tube |
| | Piston Sample |
| | Washington Undisturbed |
| | Becker Hammer |
| | Core |
| | Grab Sample |
| | Bag Sample |

| Well Symbols | |
|--------------|---|
| | Cement Surface Seal |
| | Piezometer Pipe in Granular Bentonite Seal |
| | Piezometer Pipe in Sand |
| | Well Screen in Sand |
| | Granular Bentonite Bottom Seal |
| | Inclinometer Casing in Concrete Bentonite Grout |

| Laboratory Testing Codes | |
|--------------------------|-----------------------------------|
| UU | Unconsolidated Undrained Triaxial |
| CU | Consolidated Undrained Triaxial |
| CD | Consolidated Drained Triaxial |
| UC | Unconfined Compression Test |
| DS | Direct Shear Test |
| CN | Consolidation Test |
| GS | Grain Size Distribution |
| MC | Moisture Content |
| SG | Specific Gravity |
| OR | Organic Content |
| DN | Density |
| AL | Atterberg Limits |
| PT | Point Load Compressive Test |
| SL | Slake Test |
| DG | Degradation |
| LA | LA Abrasion |

| Soil Density Modifiers | | | |
|---------------------------------|--------------|------------------------|--------------|
| Gravel, Sand & Non-plastic Silt | | Elastic Silts and Clay | |
| SPT Blows/ft | Density | SPT Blows/ft | Consistency |
| 0-4 | Very Loose | 0-1 | Very Soft |
| 5-10 | Loose | 2-4 | Soft |
| 11-24 | Medium Dense | 5-8 | Medium Stiff |
| 25-50 | Dense | 9-15 | Stiff |
| >50 | Very Dense | 16-30 | Very Stiff |
| | | 31-60 | Hard |
| | | >60 | Very Hard |

| Angularity of Gravel & Cobbles | |
|--------------------------------|---|
| Angular | Coarse particles have sharp edges and relatively plane sides with unpolished surfaces. |
| Subangular | Coarse grained particles are similar to angular but have rounded edges. |
| Subrounded | Coarse grained particles have nearly plane sides but have well rounded corners and edges. |
| Rounded | Coarse grained particles have smoothly curved sides and no edges. |

| Soil Moisture Modifiers | |
|-------------------------|--|
| Dry | Absence of moisture; dusty, dry to touch |
| Moist | Damp but no visible water |
| Wet | Visible free water |

| Soil Structure | |
|----------------|--|
| Stratified | Alternating layers of varying material or color at least 6mm thick; note thickness and inclination. |
| Laminated | Alternating layers of varying material or color less than 6mm thick; note thickness and inclination. |
| Fissured | Breaks along definite planes of fracture with little resistance to fracturing. |
| Slickensided | Fracture planes appear polished or glossy, sometimes striated. |
| Blocky | Cohesive soil that can be broken down into smaller angular lumps which resist further breakdown. |
| Disrupted | Soil structure is broken and mixed. Infers that material has moved substantially - landslide debris. |
| Homogeneous | Same color and appearance throughout. |

| HCL Reaction | |
|---------------------|--|
| No HCL Reaction | No visible reaction. |
| Weak HCL Reaction | Some reaction with bubbles forming slowly. |
| Strong HCL Reaction | Violent reaction with bubbles forming immediately. |

| Degree of Vesicularity of Pyroclastic Rocks | |
|---|----------------------------------|
| Slightly Vesicular | 5 to 10 percent of total |
| Moderately Vesicular | 10 to 25 percent of total |
| Highly Vesicular | 25 to 50 percent of total |
| Scoriaceous | Greater than 50 percent of total |

Figure A-1



Test Boring Legend

| Grain Size | | |
|----------------|------------|---|
| Fine Grained | < 1mm | Few crystal boundaries/grains are distinguishable in the field or with hand lens. |
| Medium Grained | 1mm to 5mm | Most crystal boundaries/grains are distinguishable with the aid of a hand lens. |
| Coarse Grained | > 5mm | Most crystal boundaries/grains are distinguishable with the naked eye. |

| Weathered State | | |
|----------------------|---|------------|
| Term | Description | Grade |
| Fresh | No visible sign of rock material weathering; perhaps slight discoloration in major discontinuity surfaces. | I |
| Slightly Weathered | Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than its fresh condition. | II |
| Moderately Weathered | Less than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as a continuous framework or as core stones. | III |
| Highly Weathered | More than half of the rock material is decomposed and/or disintegrated to soil. Fresh or discolored rock is present either as discontinuous framework or as core stone. | IV |
| Completely Weathered | All rock material is decomposed and/or disintegrated to soil. The original mass structure is still largely intact. | V |
| Residual Soil | All rock material is converted to soil. The mass structure and material fabric is destroyed. There is a large change in volume, but the soil has not been significantly transported. | VI |

| Relative Rock Strength | | | |
|------------------------|-------------------|---|--------------------------------------|
| Grade | Description | Field Identification | Uniaxial Compressive Strength approx |
| R1 | Very Weak | Specimen crumbles under sharp blow from point of geological hammer, and can be cut with a pocket knife. | 1 to 25 MPa |
| R2 | Moderately Weak | Shallow cuts or scrapes can be made in a specimen with a pocket knife. Geological hammer point indents deeply with firm blow. | 25 to 50 MPa |
| R3 | Moderately Strong | Specimen cannot be scraped or cut with a pocket knife, shallow indentation can be made under firm blows from a hammer. | 50 to 100 MPa |
| R4 | Strong | Specimen breaks with one firm blow from the hammer end of a geological hammer. | 100 to 200 MPa |
| R5 | Very Strong | Specimen requires many blows of a geological hammer to break intact sample. | Greater than 200 MPa |

| Discontinuities | | | |
|---|------------------|-----------|---|
| Spacing | | Condition | |
| Very Widely | Greater than 3 m | Excellent | Very rough surfaces, no separation, hard discontinuity wall |
| Widely | 1 m to 3 m | Good | Slightly rough surfaces, separation less than 1 mm, hard discontinuity wall. |
| Moderately | 0.3 m to 1 m | Fair | Slightly rough surfaces, separation greater than 1 mm, soft discontinuity wall. |
| Closely | 50 mm to 300 mm | Poor | Slickensided surfaces, or soft gouge less than 5 mm thick, or open discontinuities 1 to 5 mm. |
| Very Closely | Less than 50 mm | Very Poor | Soft gouge greater than 5 mm thick, or open discontinuities greater than 5 mm. |
| RQD (%) | | | |
| $\frac{100(\text{length of core in pieces} > 100\text{mm})}{\text{Length of core run}}$ | | | |

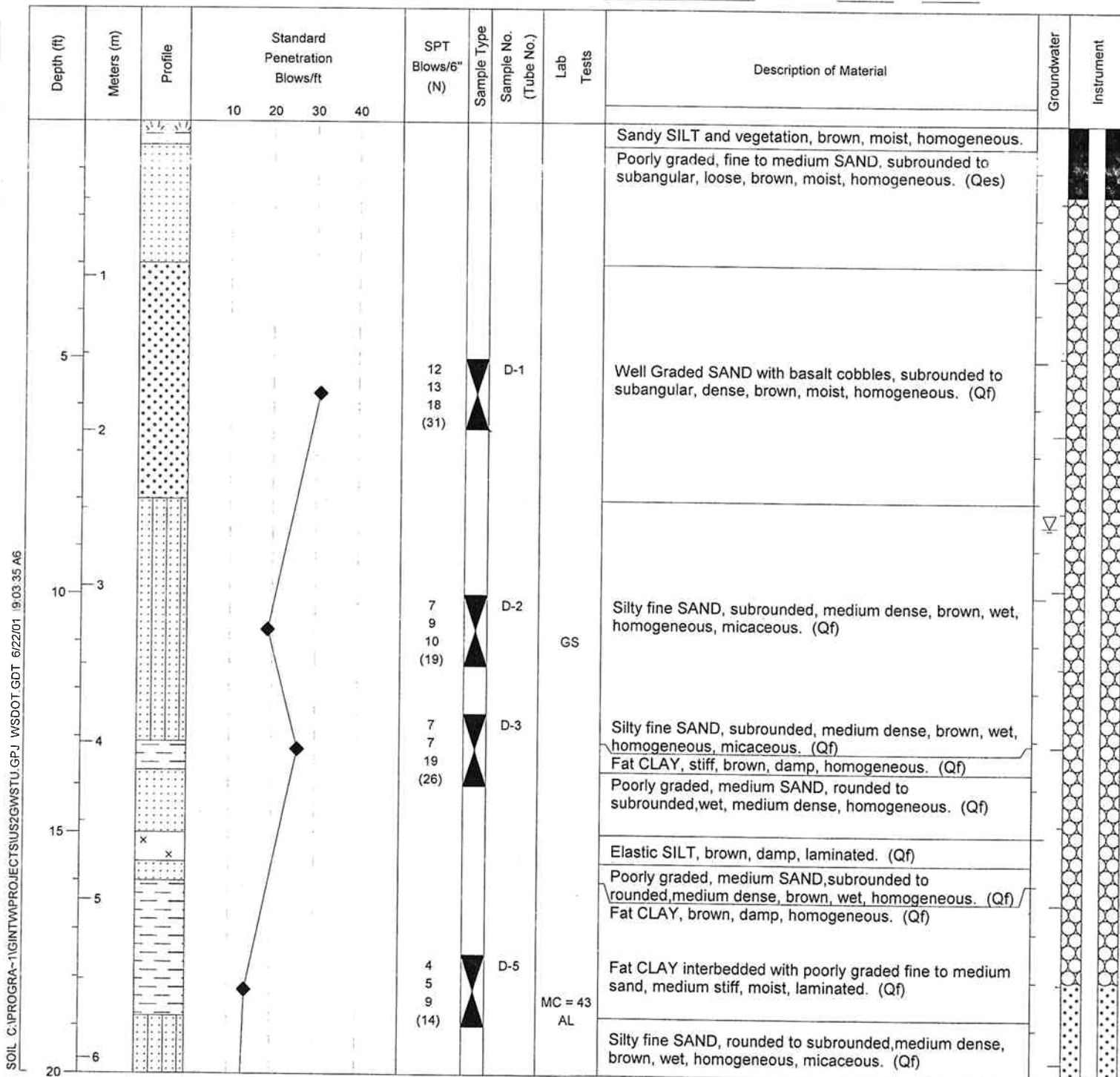
Fracture Frequency (FF) is the average number of fractures per 300 mm of core.
Does not include mechanical breaks caused by drilling or handling.

Figure A-1

LOG OF TEST BORING

Washington State
Department of TransportationHOLE No. **US2-4D-01**PROJECT **SR395 US2 GROUNDWATER STUDY**Job No. **XL0715****Spokane, Washington**S.R. **395**Station **469+39.420**Offset **862.94**

C.S.

Equipment **B-61**Casing **8-Inch HSA**Ground El **1833.3 (558.79 m)**Method of Boring **8-Inch Hollow Stem Auger**Start Date **March 28, 2001**Completion Date **March 28, 2001**Sheet **1** of **3**

LOG OF TEST BORING



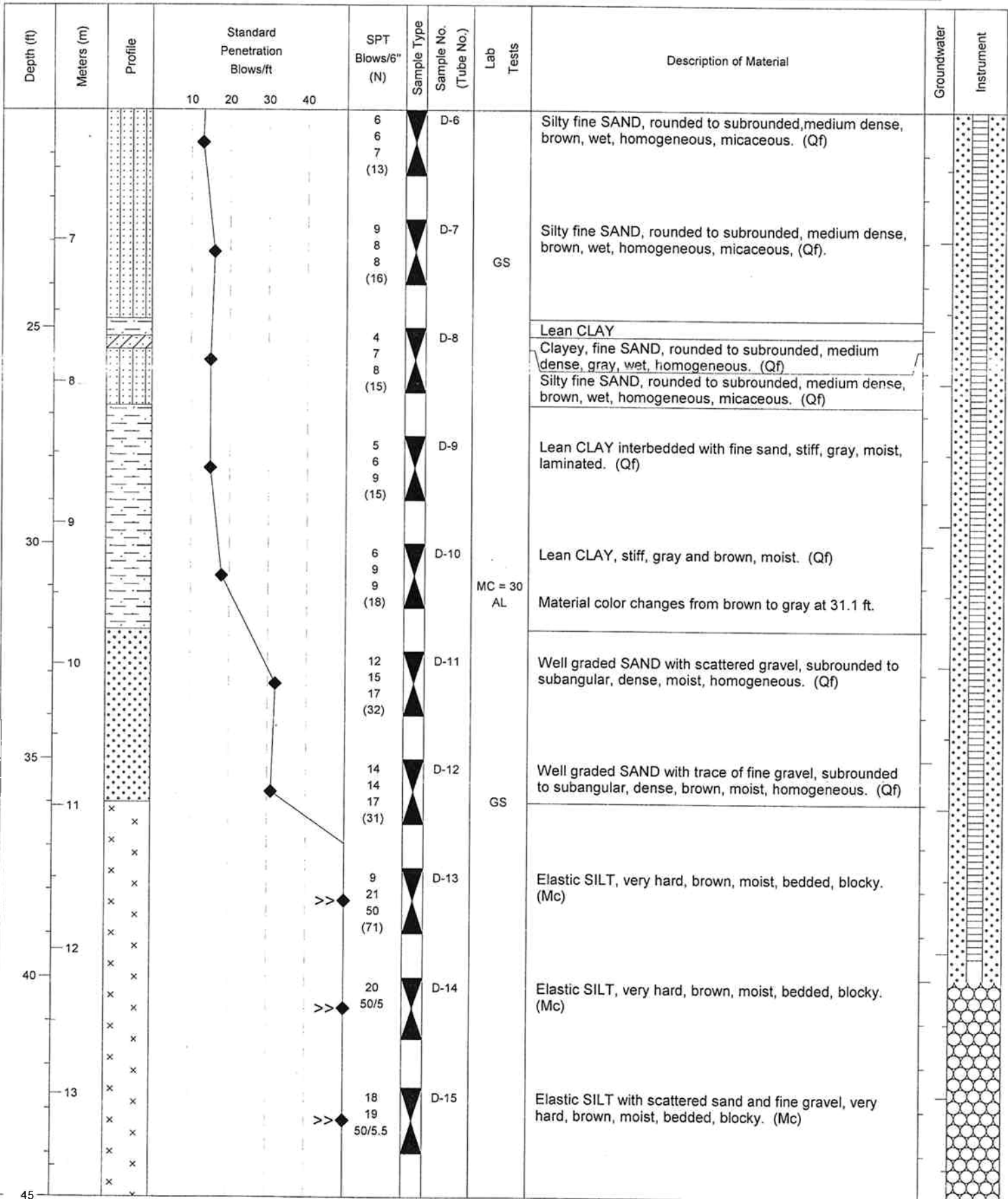
Washington State
Department of Transportation

HOLE No. **US2-4D-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Sheet **2** of **3**
Job No. **XL0715**

SOIL C:\PROGRA-1\GINTW\PROJECTS\US2GWSTU.GPJ WSDOT.GDT 6/22/01 9:03:36 A6



HOLE No. **US2-4D-01**

PROJECT SR395 US2 GROUNDWATER STUDY

Sheet 3 of 3
Job No. XL0715

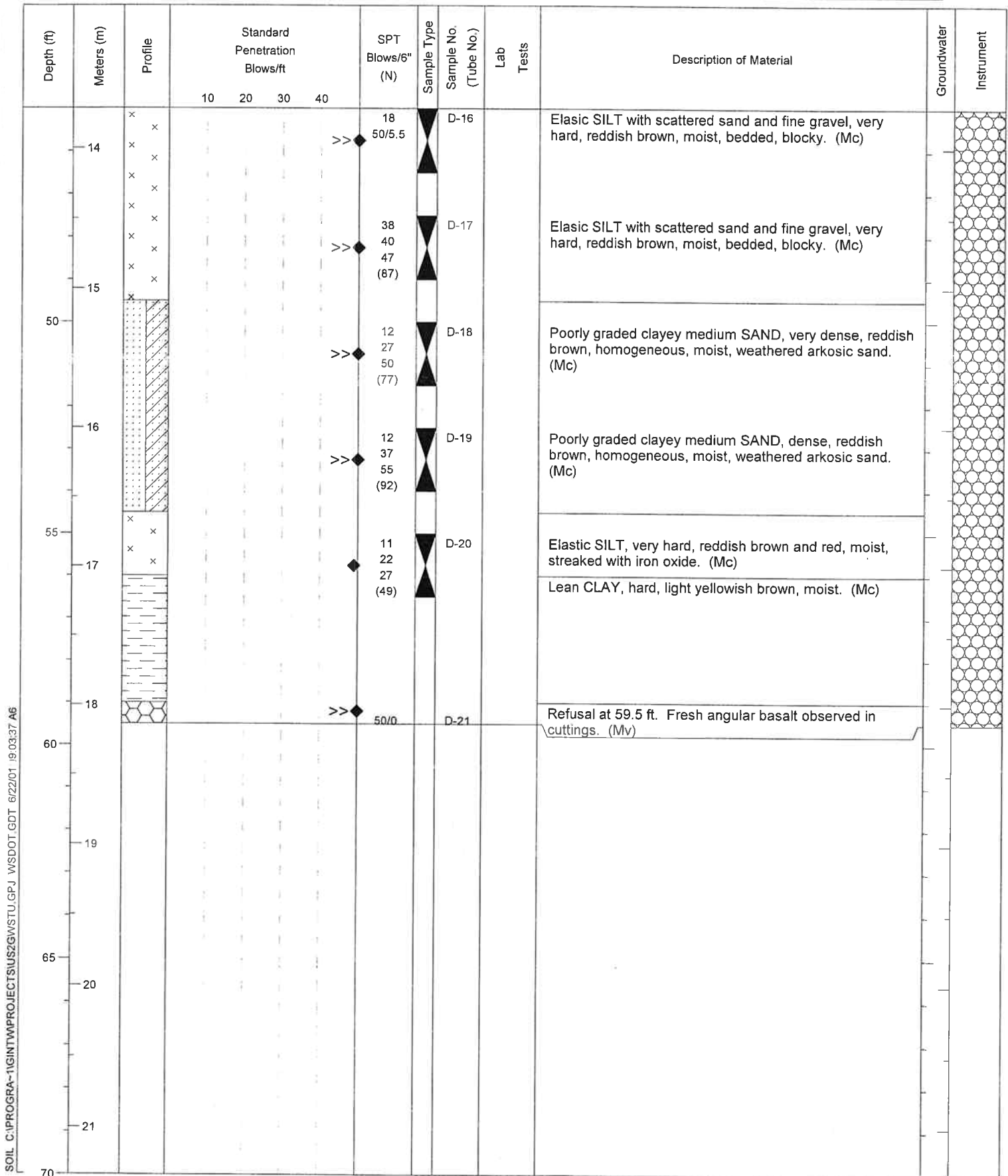
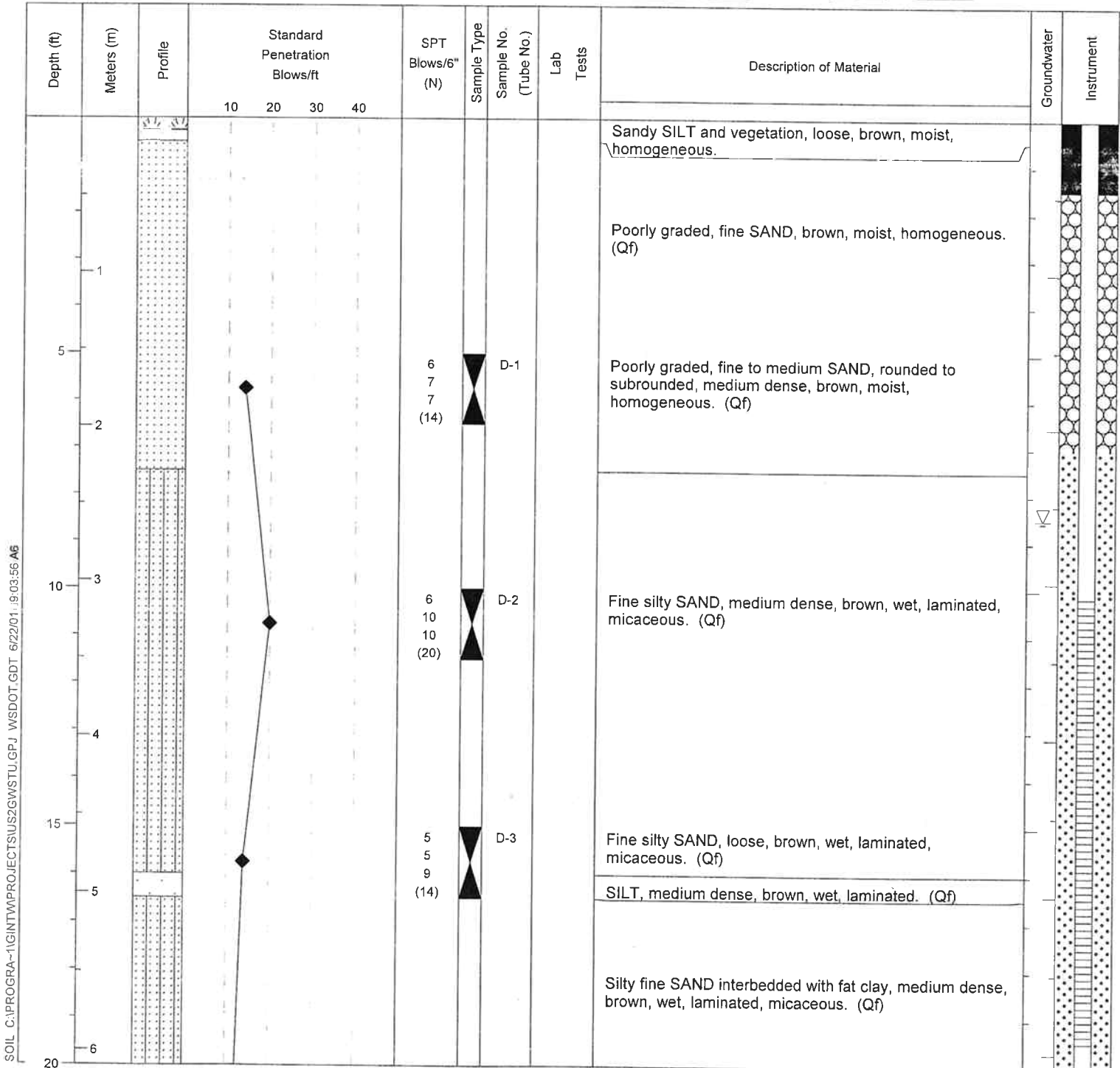


Figure A-2 Page (3 of 3)

LOG OF TEST BORING

Washington State
Department of TransportationHOLE No. **US2-4S-01**PROJECT **SR395 US2 GROUNDWATER STUDY**Job No. **XL0715****Spokane, Washington**S.R. **395**Station **469+25.916**Offset **871.02**

C.S. _____

Equipment **B-61**Casing **8-Inch HSA**Ground El **1833.0 (558.70 m)**Method of Boring **8-Inch Hollow Stem Auger**Start Date **April 2, 2001**Completion Date **April 2, 2001**Sheet **1** of **2**

LOG OF TEST BORING



Washington State
Department of Transportation

HOLE No. **US2-4S-01**

Sheet **2** of **2**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Job No. **XL0715**

| Depth (ft) | Meters (m) | Profile | Standard Penetration Blows/ft | | | | SPT Blows/6" (N) | Sample Type Sample No. (Tube No.) | Lab Tests | Description of Material | Groundwater | Instrument |
|------------|------------|---------|-------------------------------|----|----|----|---------------------|---|-----------|---|-------------|------------|
| | | | 10 | 20 | 30 | 40 | | | | | | |
| | | | | | | | 2 5 7 (12) | D-4 | | Silty fine SAND interbedded with fat clay, medium dense, brown, wet, laminated, micaceous. (Qf) | | |
| 7 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 40 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |

SOIL C:\PROGRAM-1\GINT\PROJECTS\US2GWSTU.GPJ WSDOT GDT 6/22/01 19:03:57 A6

LOG OF TEST BORING

Washington State
Department of TransportationHOLE No. US2-5-01PROJECT SR395 US2 GROUNDWATER STUDYJob No. XL0715Spokane, WashingtonS.R. 395Station 467+91.017Offset 834.15

C.S. _____

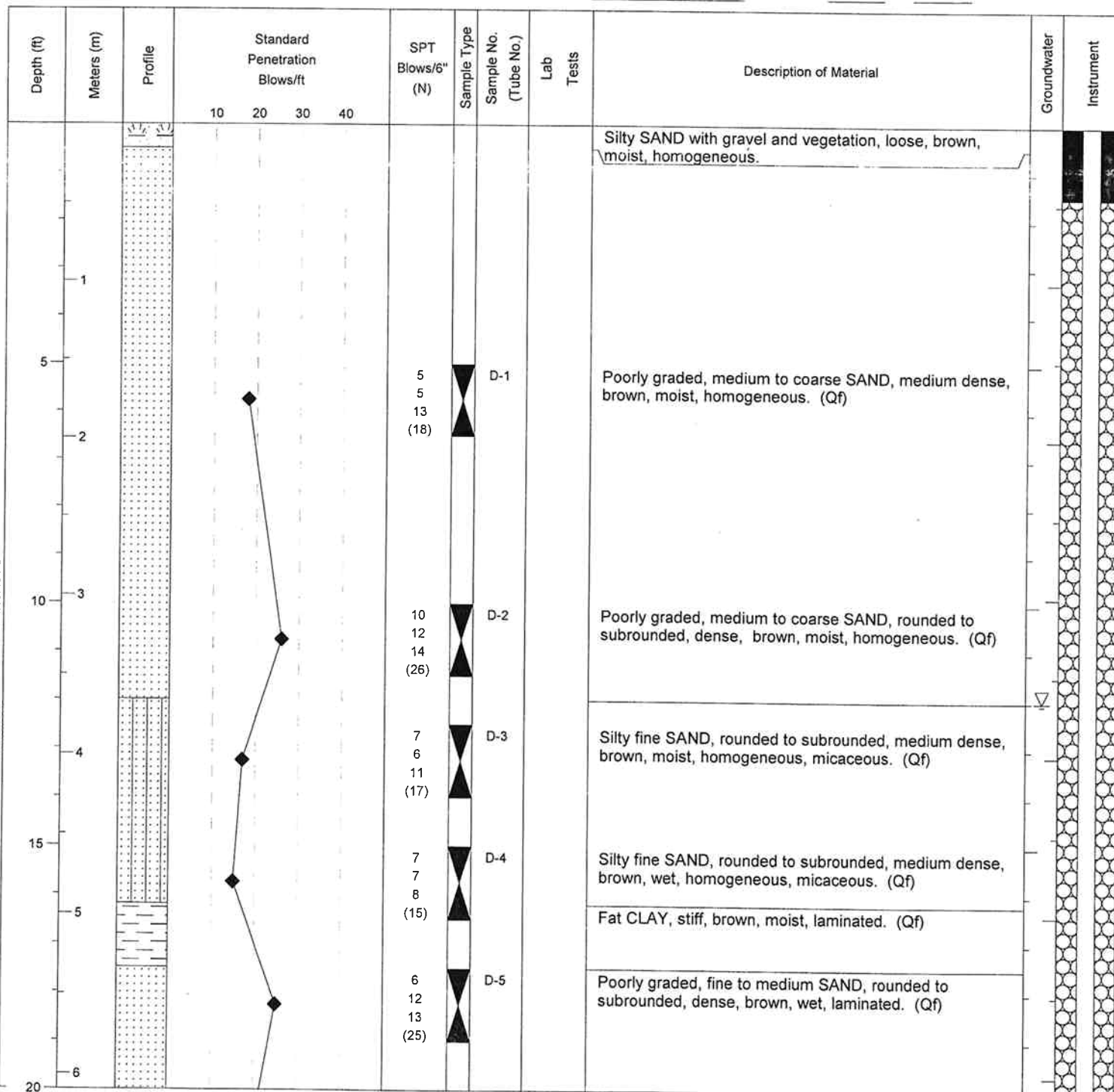
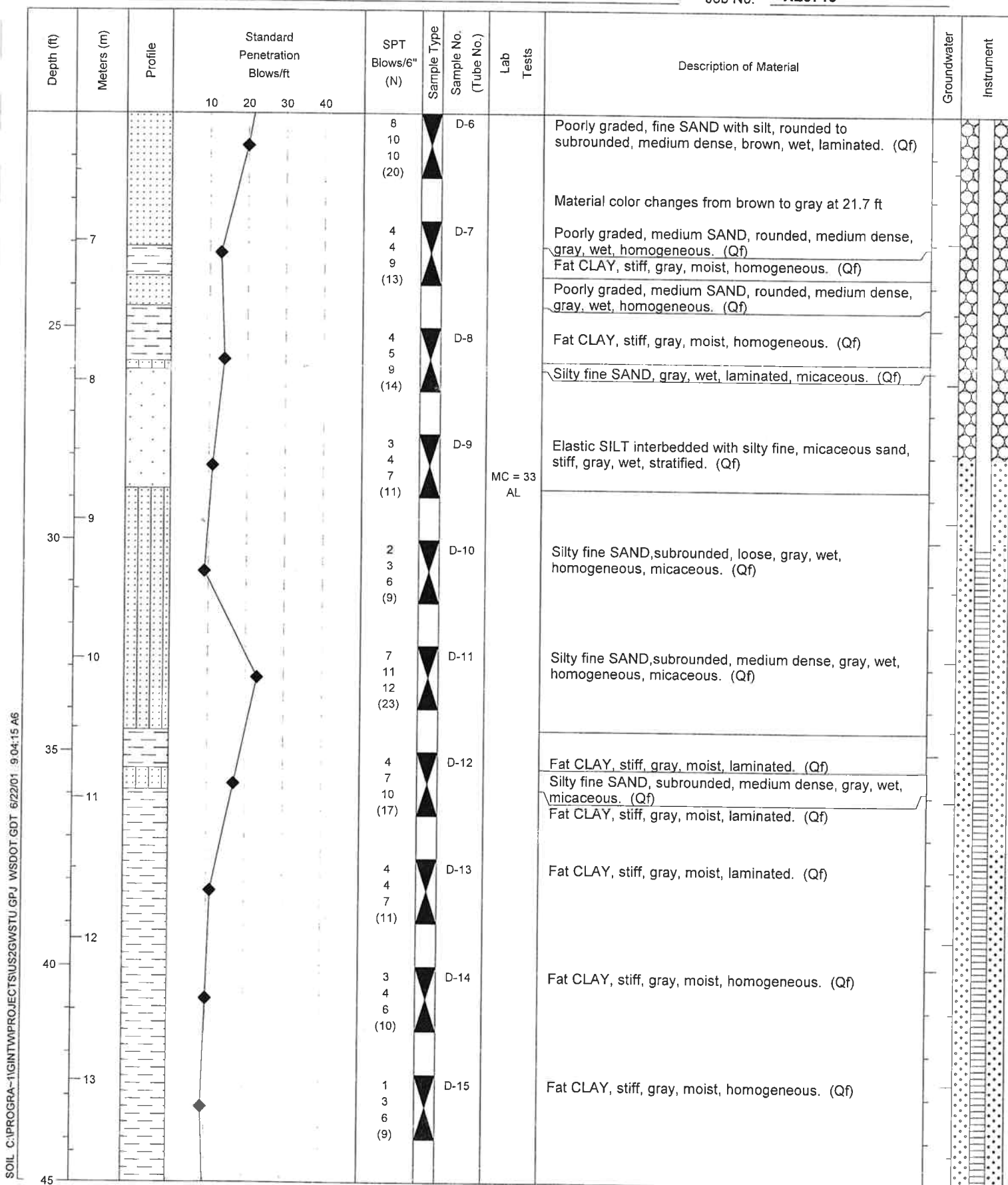
Equipment B-61Casing 8-Inch HSAGround El 1836.5 (559.77 m)Method of Boring 8-Inch Hollow Stem AugerStart Date March 29, 2001Completion Date March 30, 2001Sheet 1 of 4

Figure A-4 Page (1 of 4)

LOG OF TEST BORING

Washington State
Department of TransportationHOLE No. **US2-5-01**PROJECT **SR395 US2 GROUNDWATER STUDY**Sheet **2** of **4**Job No. **XL0715**

LOG OF TEST BORING



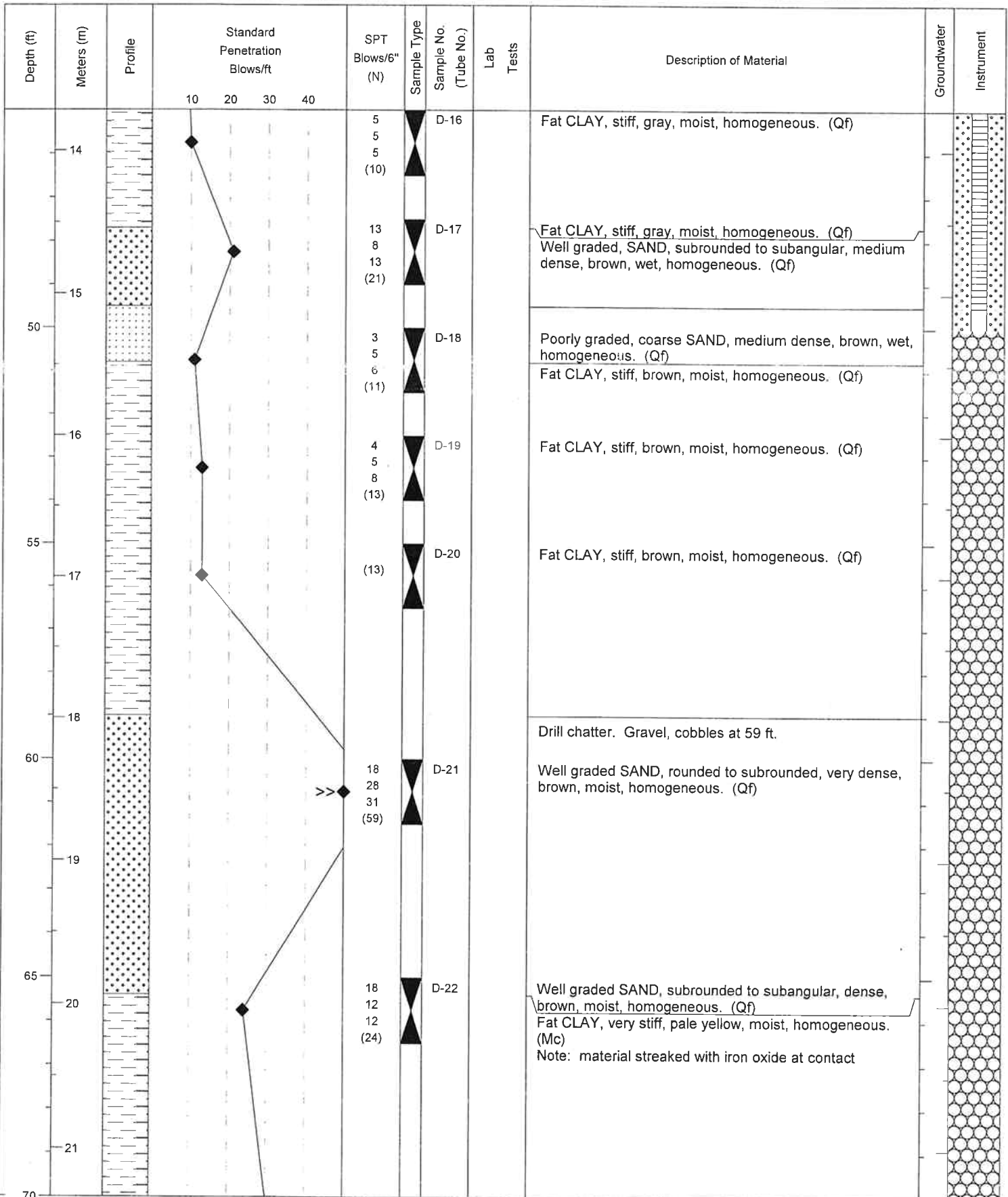
Washington State
Department of Transportation

HOLE No. **US2-5-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Sheet **3** of **4**
Job No. **XL0715**

SOIL C:\PROGRAM-1\GINT\PROJECTS\US2\GWSTU.GPJ WSDOT.GDT 6/22/01 19:04:16 AG



LOG OF TEST BORING





Washington State
Department of Transportation

HOLE No. **US2-5-01**

Sheet **4** of **4**
Job No. **XL0715**

PROJECT **SR395 US2 GROUNDWATER STUDY**

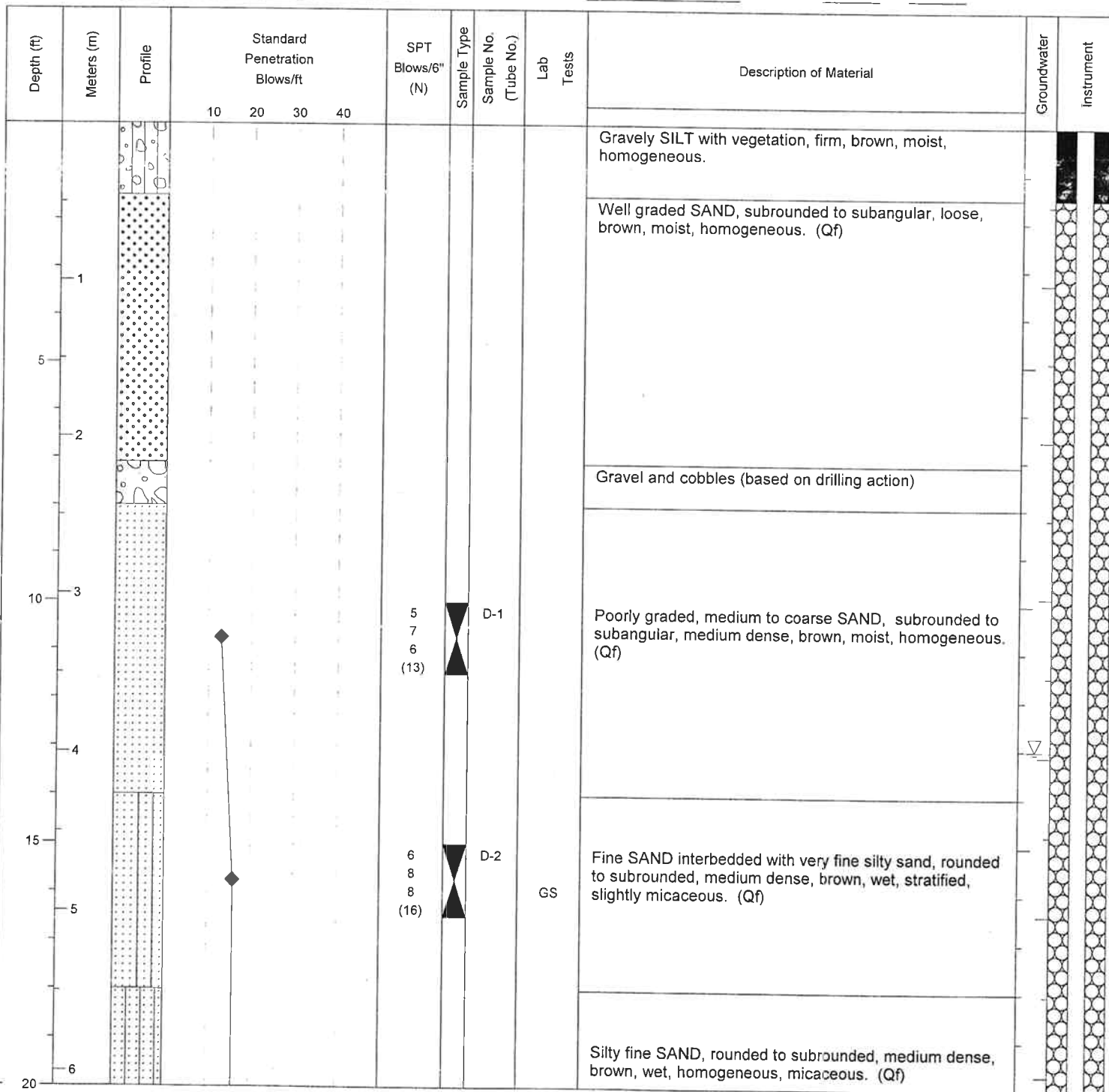
SOIL C:\PROGRA-1\GINTW\PROJECTS\US2\GWSTU.GPJ WSDOT.GDT 6/22/01 11:04:18 A6

| Depth (ft) | Meters (m) | Profile | Standard Penetration Blows/ft | | | | SPT Blows/6" (N) | Sample Type Sample No. (Tube No.) | Lab Tests | Description of Material | Groundwater | Instrument |
|------------|------------|---|-------------------------------|----|----|----|-----------------------|---|-----------|---|-------------|---|
| | | | 10 | 20 | 30 | 40 | | | | | | |
| | |  | | | ◆ | | 7 13 18 (31) | D-23 | | Fat CLAY, hard, yellow and reddish yellow, moist, laminated, streaked with iron oxide. (Mc) | |  |
| 22 | | | | | | | | | | | | |
| 75 | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | |
| 80 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |
| 85 | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | |
| 90 | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | |
| 95 | | | | | | | | | | | | |

LOG OF TEST BORING

Washington State
Department of TransportationHOLE No. **US2-6-01**PROJECT **SR395 US2 GROUNDWATER STUDY**Job No. **XL0715****Spokane, Washington**S.R. **395**Station **468+99.448**Offset **988.62**

C.S.

Equipment **B-61**Casing **8-Inch HSA**Ground El **1836.6 (559.80 m)**Method of Boring **8-Inch Hollow Stem Auger**Start Date **April 3, 2001**Completion Date **April 4, 2001**Sheet **1** of **3**

LOG OF TEST BORING



Washington State
Department of Transportation

HOLE No. **US2-6-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Sheet **2** of **3**
Job No. **XL0715**

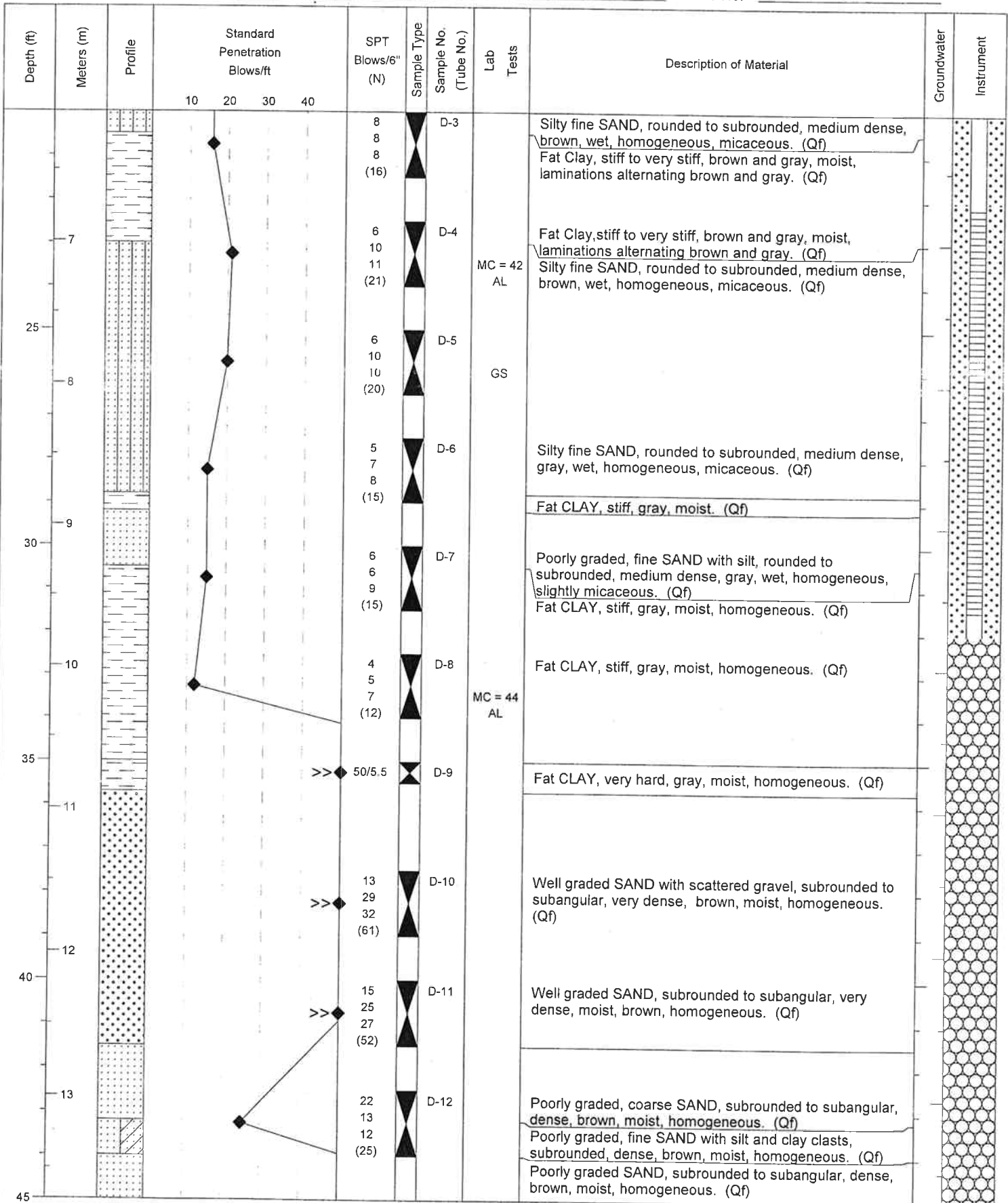


Figure A-5 Page (2 of 3)

LOG OF TEST BORING



Washington State
Department of Transportation

HOLE No. **US2-6-01**

Sheet **3** of **3**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Job No. **XL0715**

| Depth (ft) | Meters (m) | Profile | Standard Penetration Blows/ft | | | | SPT Blows/6" (N) | Sample Type | Sample No. (Tube No.) | Lab Tests | Description of Material | Groundwater | Instrument |
|------------|------------|---------|-------------------------------|----|----|----|------------------|-------------|-----------------------|-----------|--|-------------|------------|
| | | | 10 | 20 | 30 | 40 | | | | | | | |
| 14 | | | | | | | >> 35 50/1 | ◆ | D-13 | | Poorly graded SAND, subrounded to subangular, very dense, brown, moist, homogeneous. (Qf) | | |
| | | | | | | | >> 50/5.5 | ◆ | D-14 | | Well graded SAND with scattered basalt gravel, subrounded to subangular, very dense, brown, moist, homogeneous. (Qf) Poorly graded, fine SAND, subrounded, very dense, gray, moist, homogeneous. (Qf) BASALT bedrock (Mv). Inferred by drill cuttings. | | |
| 15 | | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | | |
| | | | | | | | | | | | Note: Well was installed in boring 10 ft north of boring used to acquire the above data. The initial boring was abandoned due to difficulties with heaving sand | | |
| 16 | | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | |
| 70 | | | | | | | | | | | | | |

SOIL C:\PROGRAM-1\GINT\PROJECTS\US2\GWSTU.GPJ WSDOT.GDT 6/22/01 9:04:45 AM

LOG OF TEST BORING



Washington State
Department of Transportation

HOLE No. **US2-7-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Job No. **XL0715**

Spokane, Washington

S.R. **395**

Station **471+23.568**

Offset **1087.92**

C.S.

Equipment **B-61**

Casing **8-Inch HSA**

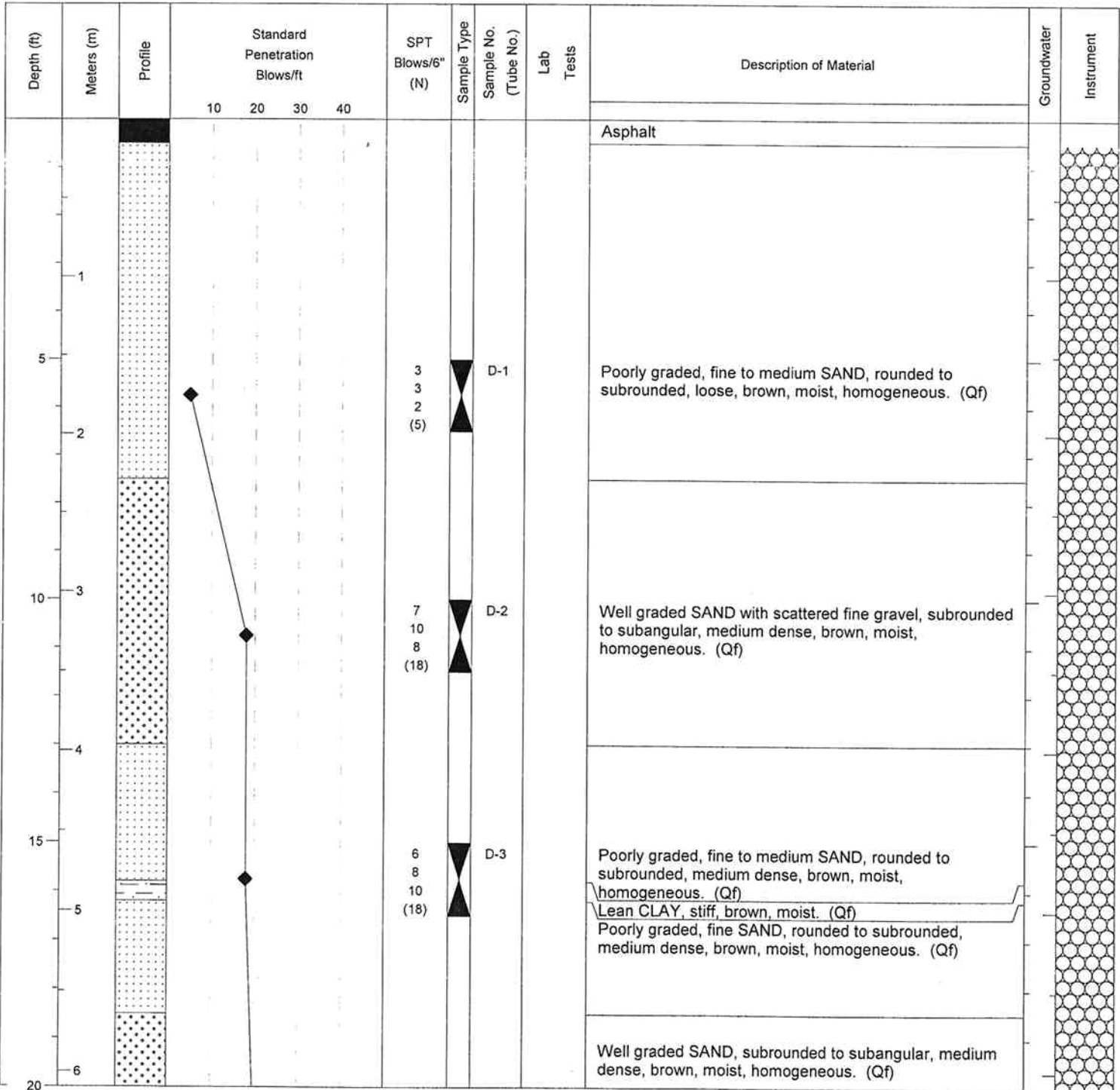
Ground El **1840.9 (561.11 m)**

Method of Boring **8-Inch Hollow Stem Auger**

Start Date **April 2, 2001**

Completion Date **April 3, 2001**

Sheet **1** of **2**



LOG OF TEST BORING

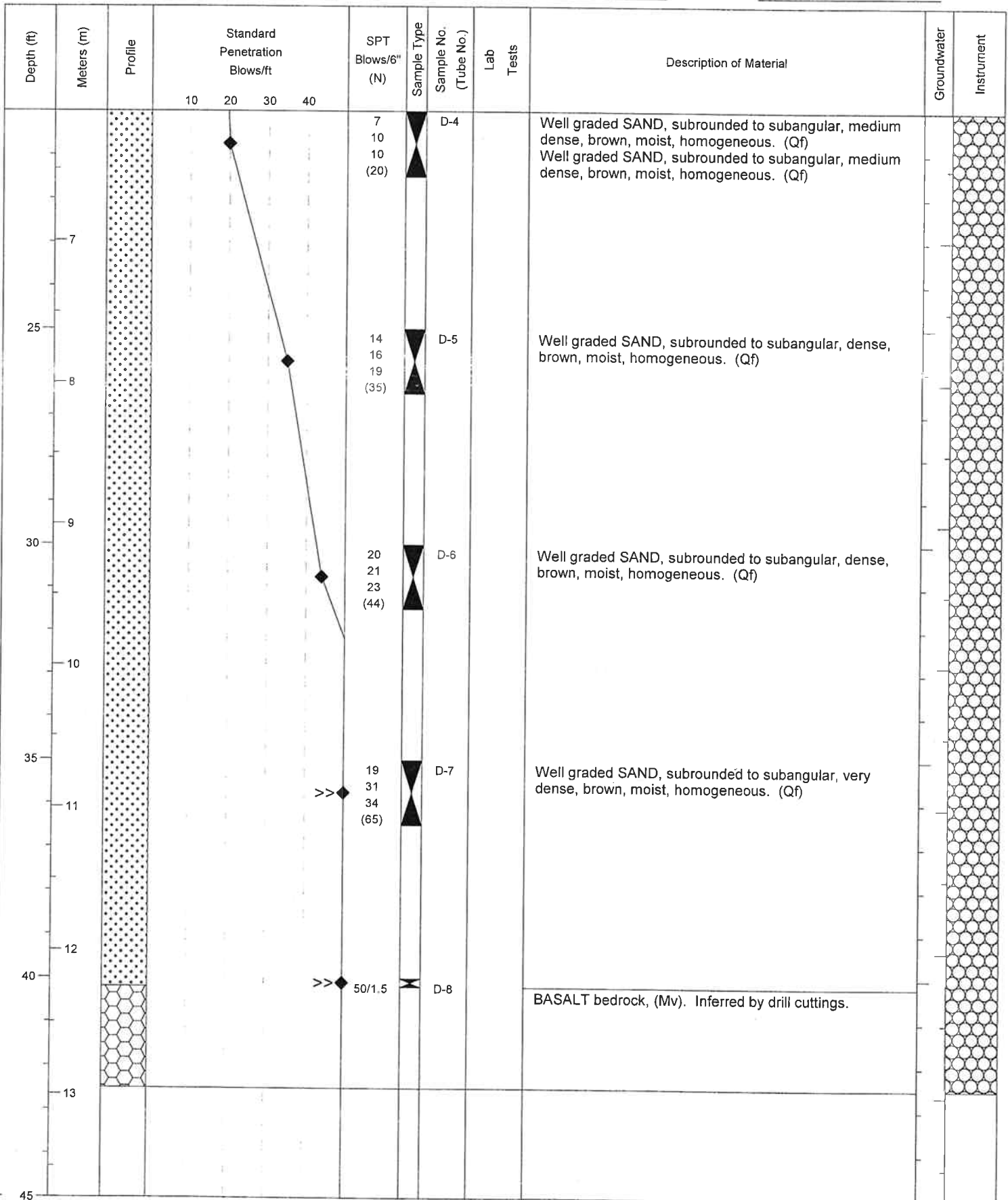


Washington State
Department of Transportation

HOLE No. **US2-7-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Sheet **2** of **2**
Job No. **XL0715**



SOIL C:\PROGRA-1\GINT\PROJECTS\US2\GWSTU.GPJ WSDOT.GDT 6/22/01 9:05:05 A6

LOG OF TEST BORING

Washington State
Department of TransportationHOLE No. **US2-9-01**PROJECT **SR395 US2 GROUNDWATER STUDY**Job No. **XL0715****Spokane, Washington**S.R. **395**Station **469+27.357**Offset **890.33**

C.S.

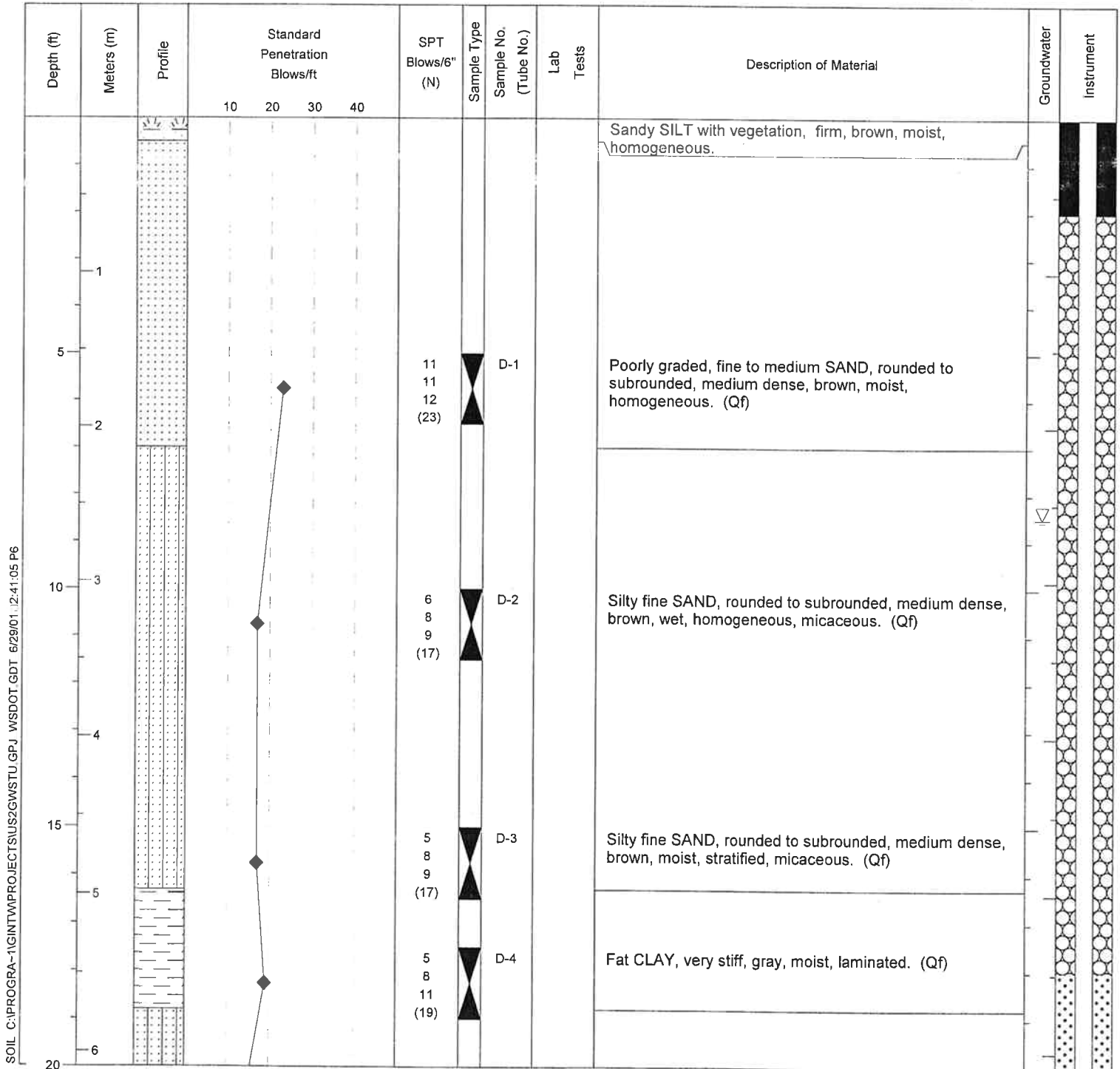
Equipment **B-61**Casing **8-Inch HSA**Ground El **1832.8 (558.64 m)**Method of Boring **8-Inch Hollow Stem Auger**Start Date **April 25, 2001**Completion Date **April 26, 2001**Sheet **1** of **3**

Figure A-7 Page (1 of 3)

LOG OF TEST BORING

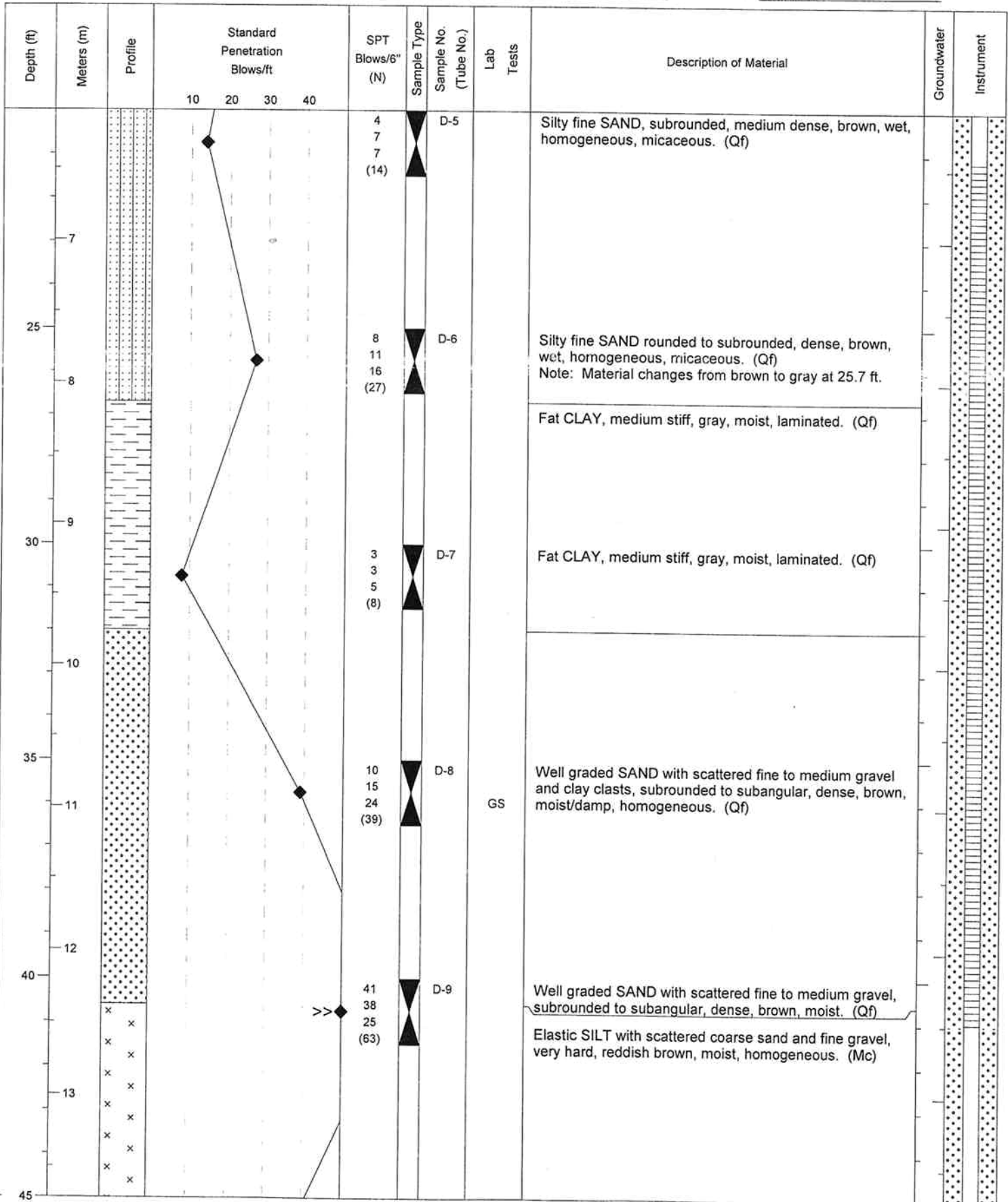


Washington State
Department of Transportation

HOLE No. **US2-9-01**

Sheet **2** of **3**
Job No. **XL0715**

PROJECT **SR395 US2 GROUNDWATER STUDY**



SOIL C:\PROGRAM-1\GINT\PROJECTS\US2\GWS\TU.GPJ WSDOT GDT 6/29/01 12:41:06 P6

LOG OF TEST BORING



Washington State
Department of Transportation

HOLE No. **US2-9-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Sheet **3** of **3**
Job No. **XL0715**

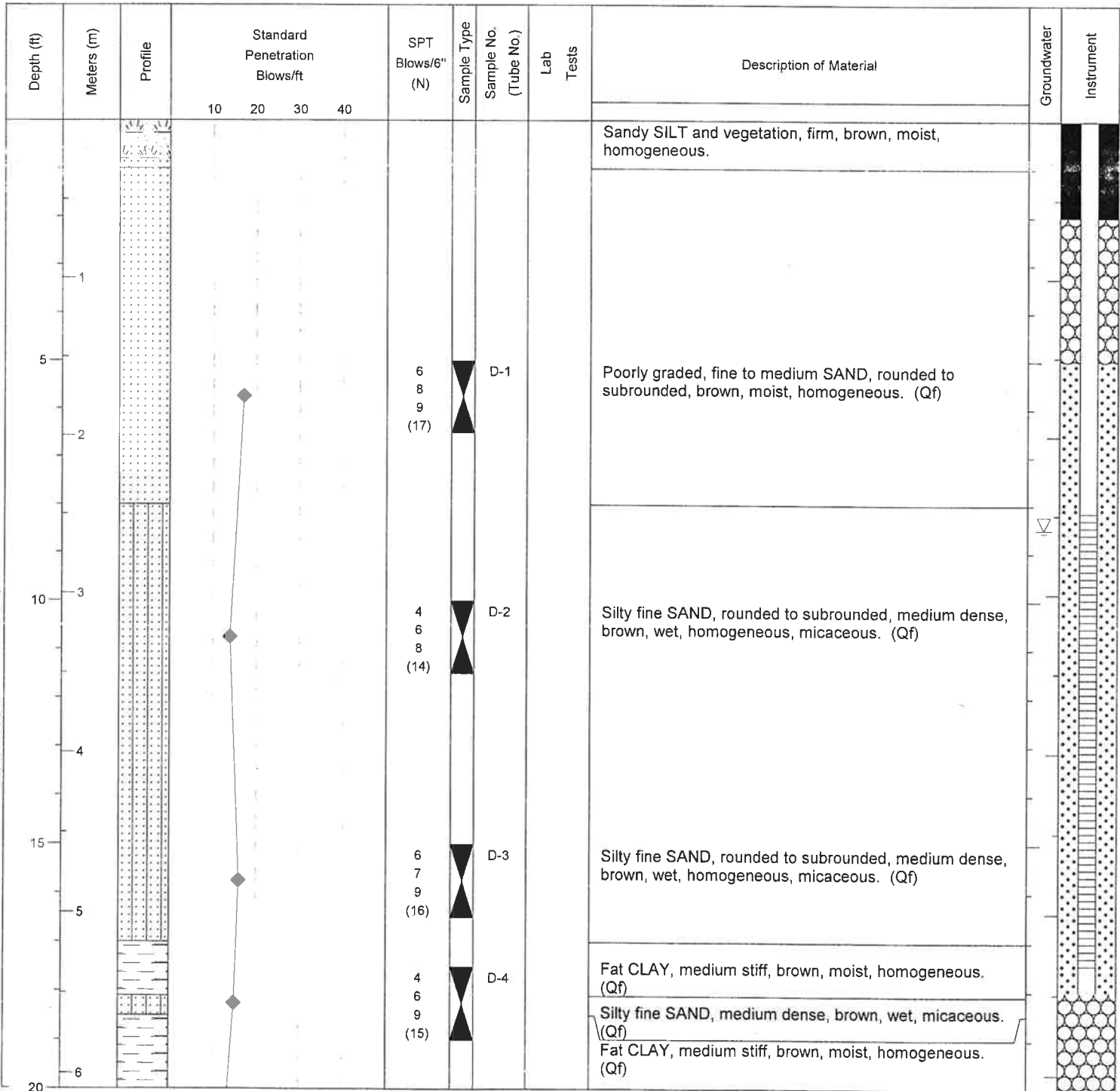
| Depth (ft) | Meters (m) | Profile | Standard Penetration Blows/ft | | | | SPT Blows/6" (N) | Sample Type | Sample No. (Tube No.) | Lab Tests | Description of Material | Groundwater | Instrument |
|------------|------------|------------------|-------------------------------|----|----|----|-----------------------|-------------|-----------------------|-----------|--|-------------|------------|
| | | | 10 | 20 | 30 | 40 | | | | | | | |
| 14 | | x x x x | | | | ◆ | 9 14 23 (37) | ▲ ▼ | D-10 | | Elastic SILT with scattered coarse sand, hard, reddish brown, moist, homogeneous. (Mc) | | |
| 15 | | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | |
| 70 | | | | | | | | | | | | | |

SOIL C:\PROGRAM-1\GINTWP\PROJECTS\US2\GWSTU.GPJ WSDOT.GDT 6/29/01 12:41:07 P6

LOG OF TEST BORING

Washington State
Department of TransportationHOLE No. **US2-10-01**PROJECT **SR395 US2 GROUNDWATER STUDY**Job No. **XL0715****Spokane, Washington**S.R. **395**Station **469+27.357**Offset **890.33**

C.S.

Equipment **B-61**Casing **8-Inch HSA**Ground El **1832.6 (558.58 m)**Method of Boring **8-Inch Hollow Stem Auger**Start Date **April 25, 2001**Completion Date **April 26, 2001**Sheet **1** of **2**

LOG OF TEST BORING



Washington State
Department of Transportation

HOLE No. **US2-10-01**

Sheet **2** of **2**
Job No. **XL0715**

PROJECT **SR395 US2 GROUNDWATER STUDY**

| Depth (ft) | Meters (m) | Profile | Standard Penetration Blows/ft | | | | SPT Blows/6" (N) | Sample Type Sample No. (Tube No.) | Lab Tests | Description of Material | Groundwater | Instrument |
|------------|------------|---------|-------------------------------|----|----|----|---------------------|---|-----------|--|-------------|------------|
| | | | 10 | 20 | 30 | 40 | | | | | | |
| | | | | | | | 4 5 8 (13) | D-5 | | Silty fine SAND, rounded to subrounded, brown, wet, homogeneous, micaceous. (Qf) | | |
| 7 | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | |
| 40 | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | |
| 45 | | | | | | | | | | | | |

SOIL C:\PROGRAM-1\GINT\PROJECTS\US2\GWSU\GPJ WSDOT GDT 6/22/01 9:03:18 A6

LOG OF TEST BORING



Washington State
Department of Transportation

HOLE No. **SSSB-3-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Job No. **XL0715**

Spokane, Washington

S.R. **395**

Station **473+66.956**

Offset **58.7**

C.S.

Equipment **B-61**

Casing **8-Inch HSA**

Ground El **1843.7 (561.96 m)**

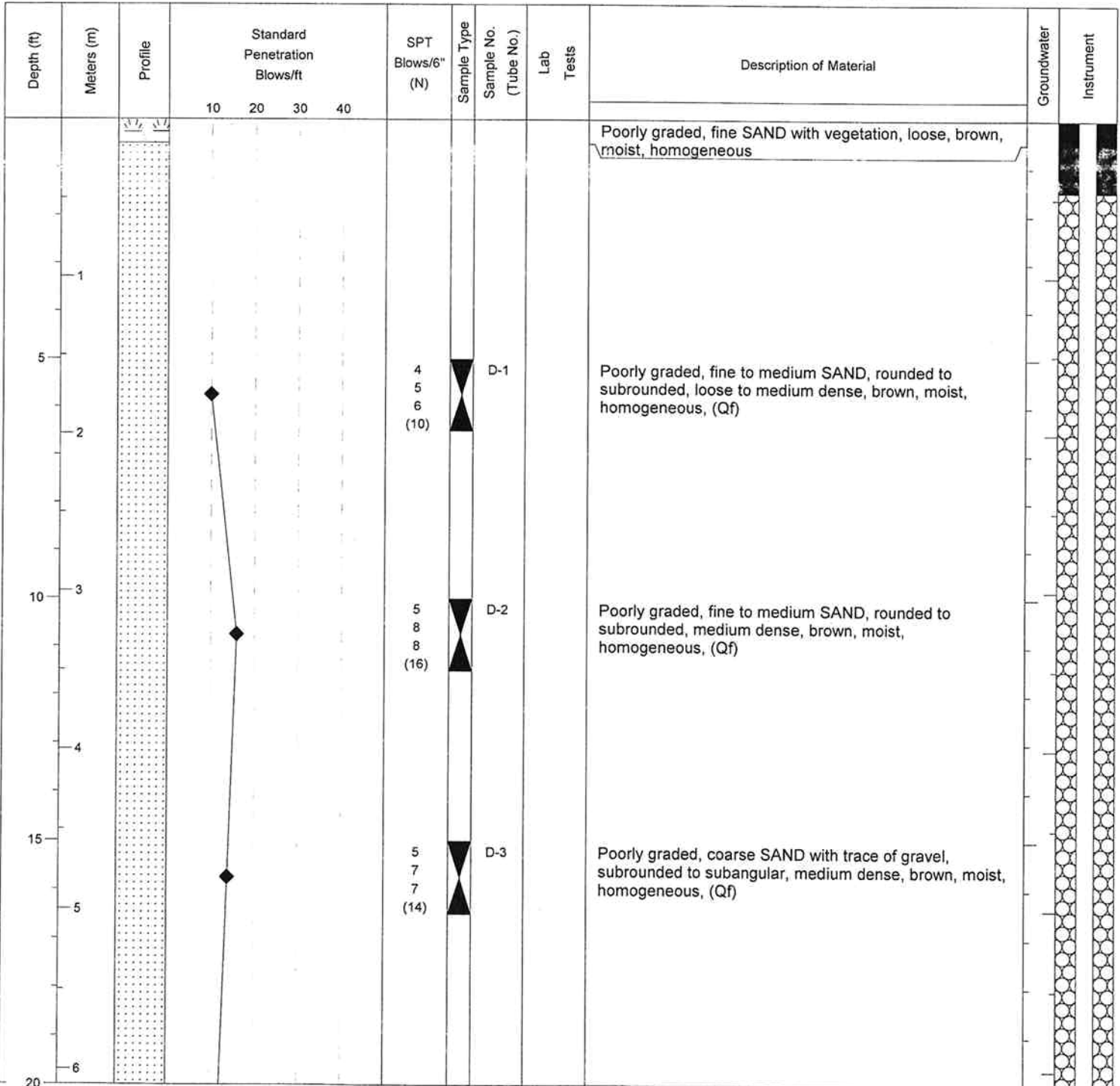
Method of Boring **8-Inch Hollow Stem Auger**

Start Date **April 2, 2001**

Completion Date **April 2, 2001**

Sheet **1** of **3**

SOIL C:\PROGRAM-1\GINTWPROJECTS\US2GWSTU GPJ WSDOT.GDT 6/22/01 9:02:59 A6



LOG OF TEST BORING



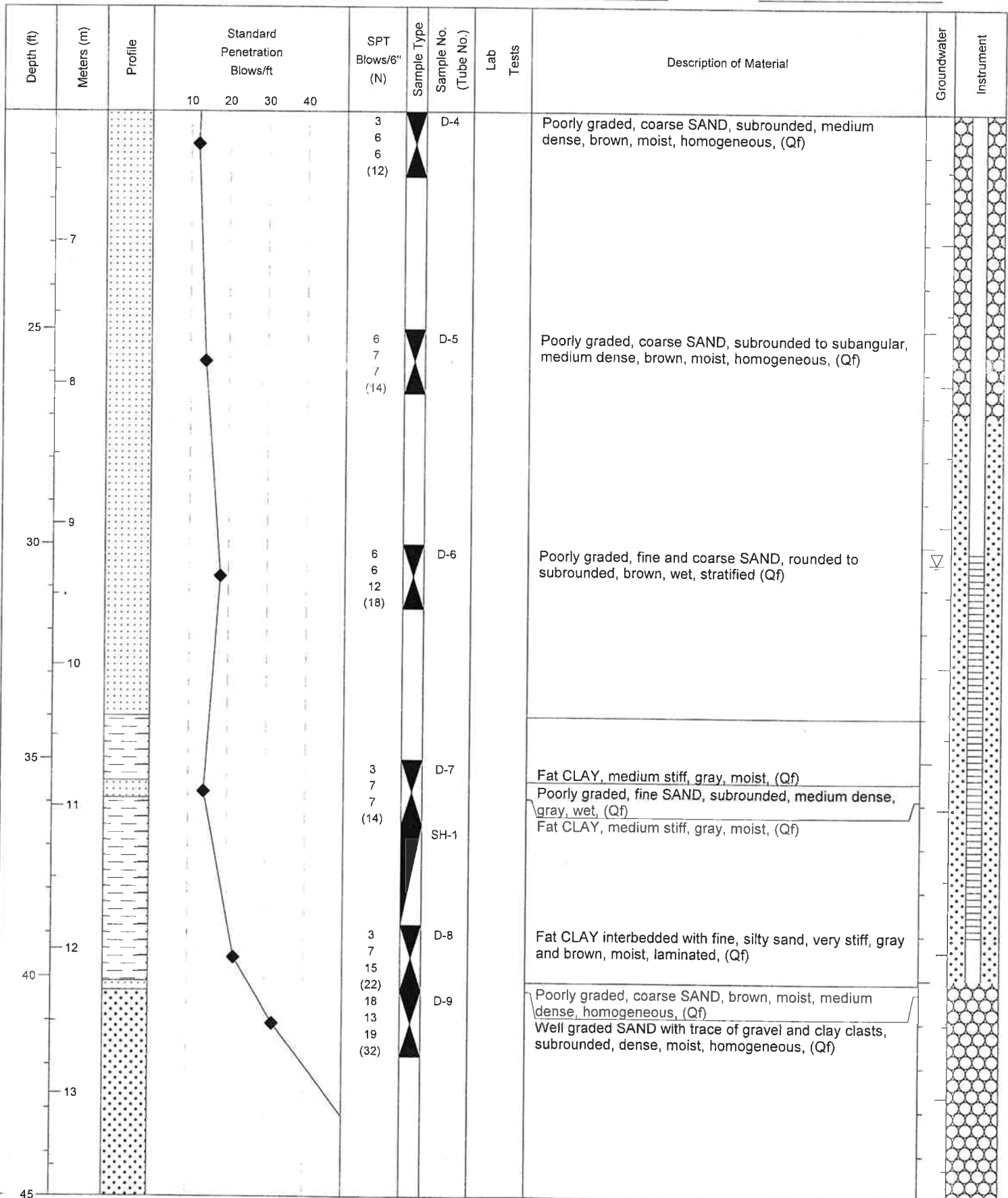
Washington State
Department of Transportation

HOLE No. **SSSB-3-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Sheet **2** of **3**
Job No. **XL0715**

SOIL C:\PROGRA-1\GINTW\PROJECTS\US2\GWSTU.GPJ WSDOT.GDT 6/22/01 9:03:00 A6



LOG OF TEST BORING




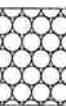
Washington State
Department of Transportation

HOLE No. **SSSB-3-01**

PROJECT **SR395 US2 GROUNDWATER STUDY**

Sheet **3** of **3**
Job No. **XL0715**

SOIL C:\PROGRAM-1\GINTWP\PROJECTS\US2GWSTU.GPJ WSDOT.GDT 6/22/01 19:03:01 A6

| Depth (ft) | Meters (m) | Profile | Standard Penetration Blows/ft | | | | SPT Blows/6" (N) | Sample Type Sample No. (Tube No.) | Lab Tests | Description of Material | Groundwater | Instrument |
|------------|------------|---|----------------------------------|----|----|----|------------------------|---|--------------|---|-------------|---|
| | | | 10 | 20 | 30 | 40 | | | | | | |
| 14 | |  | | | | | 26 33 39 (72) | D-10 | | Well graded SAND, subrounded to subangular, very dense, moist/damp, homogeneous, (Qf) | |  |
| 15 | | | | | | | | | | | | |
| 50 | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | |
| 55 | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | |
| 60 | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | |
| 65 | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | |
| 70 | | | | | | | | | | | | |

Laboratory Testing and Analytical Results

APPENDIX B LABORATORY TESTING

Natural moisture content, sieve analyses, and Atterberg Limit determinations were conducted by Soil Technology, Bainbridge Island, Washington (under subcontract to Landau Associates) on representative samples recovered from the borings for the purpose of classification and evaluation of pertinent engineering properties of soil types encountered. Laboratory testing was performed in general accordance with the American Society of Testing and Materials (ASTM) standard test procedures, which are described below. The samples were checked against the field log descriptions, which were updated where appropriate in general accordance with ASTM D2487, *Standard Test Method for Classification of Soils for Engineering Purposes*.

Natural Moisture Content

Natural moisture content determinations were performed on selected soil samples recovered from the borings in general accordance with ASTM D2216. The results are presented in Table B-1 in this appendix. Samples on which moisture content determinations were performed are designated with a "MC" on the boring logs in the column labeled "Lab Tests."

Grain Size Analyses

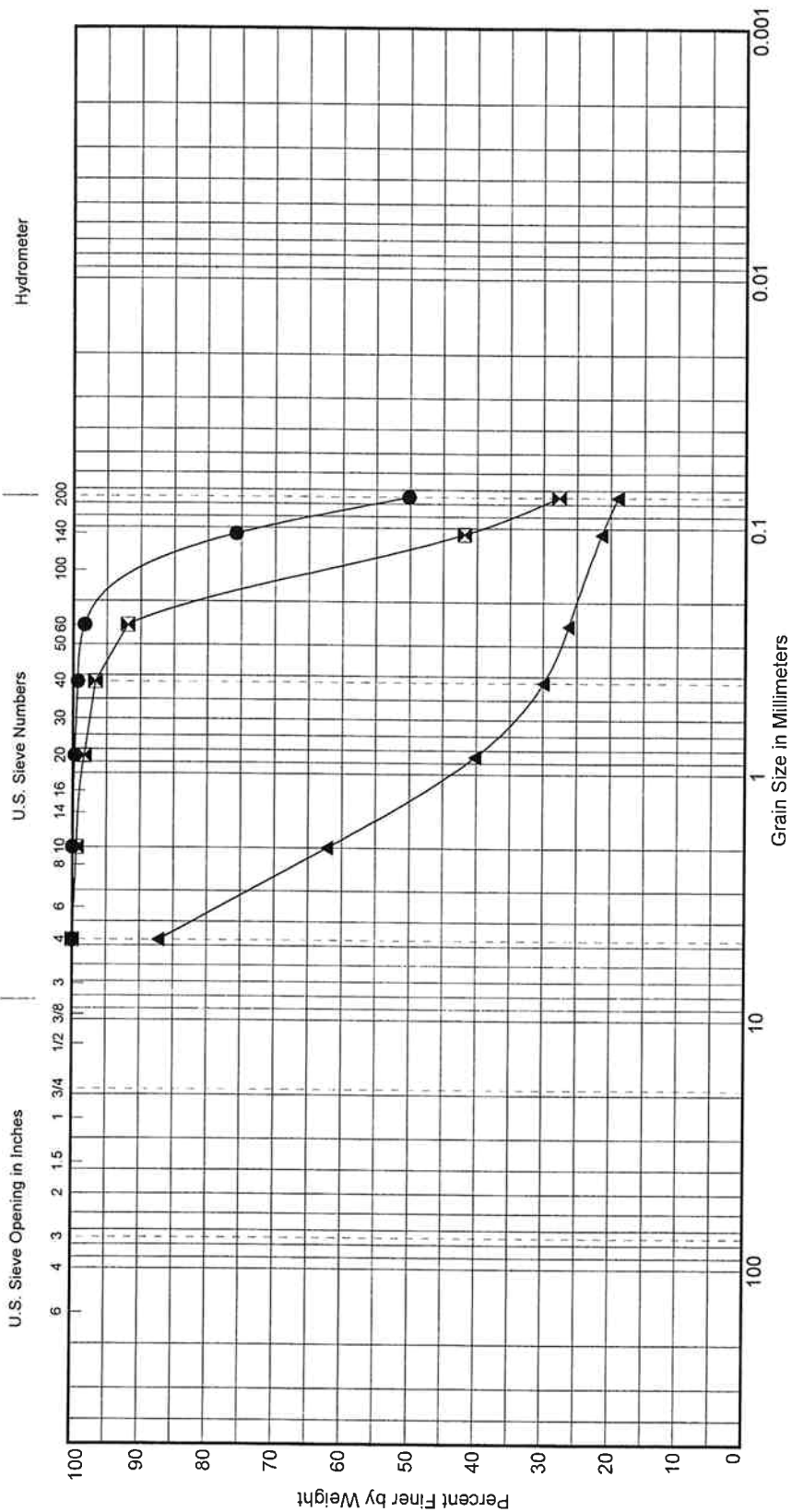
Grain size analyses were performed on representative soil samples obtained from the borings in accordance with ASTM D422 to provide an indication of their grain size distribution. The results of the sieve analyses are presented on Figures B-1, B-2, and B-3 in this appendix. Samples on which sieve analyses were completed are designated with a "GS" in the column labeled "Lab Tests" on the summary logs.

Atterberg Limit Determinations

Atterberg Limit determinations were performed on representative soil samples obtained from the borings in general accordance with ASTM D4318 to determine the liquid limit (LL), plastic limit (PL), and plasticity index (PI). The results of the Atterberg Limit determinations are presented on Figures B-4, B-5, and B-6 in this appendix. Samples on which Atterberg Limit determinations were completed are designated by "AL" in the column labeled "Lab Tests" on the summary logs.

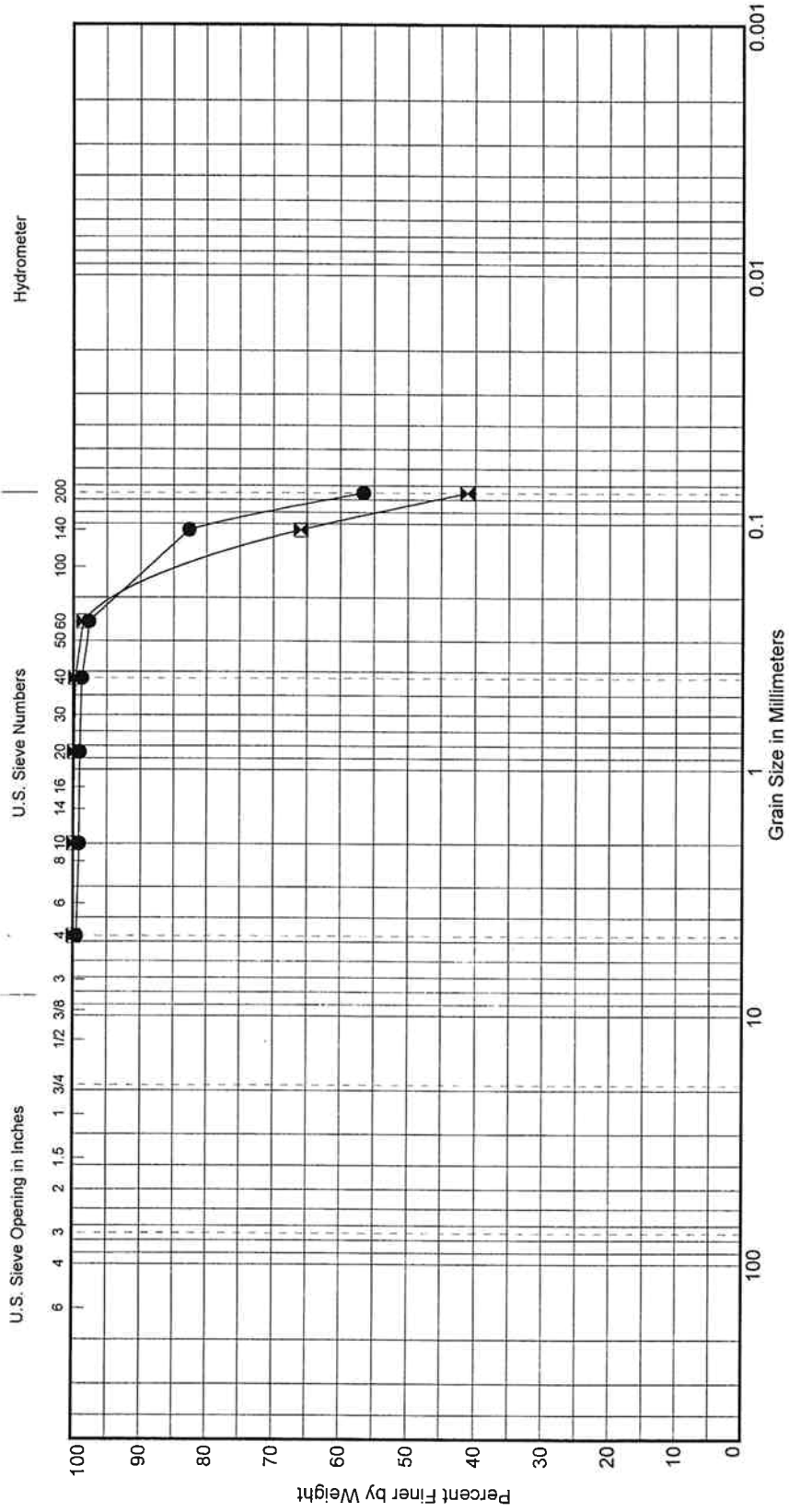
**TABLE B-1
MOISTURE CONTENT DATA**

| Exploration No. | Sample No. | Sample Depth (ft) | Moisture Content (%) |
|------------------------|-------------------|--------------------------|-----------------------------|
| US2-4D-01 | S-5 | 17.5 | 43 |
| US2-4D-01 | S-10 | 30 | 30 |
| US2-5-01 | S-9 | 27.5 | 33 |
| US2-6-01 | S-4 | 22.5 | 42 |
| US2-6-01 | S-8 | 32.5 | 44 |



| Cobbles | Gravel | | Sand | | | Silt or Clay |
|---------|--------|------|--------|--------|------|--------------|
| | Coarse | Fine | Coarse | Medium | Fine | |

| Symbol | Exploration Number | Sample Number | Depth (ft) | Natural Moisture (%) | Soil Description | Unified Soil Classification |
|--------|--------------------|---------------|------------|----------------------|---|-----------------------------|
| ● | US2-4D-01 | D-2 | 10.0 | | Fine sandy SILT | ML |
| ⊠ | US2-4D-01 | D-7 | 22.5 | | Silty fine SAND | SM |
| ▲ | US2-4D-01 | D-12 | 35.0 | | Silty, fine to coarse SAND with trace of gravel | SM |

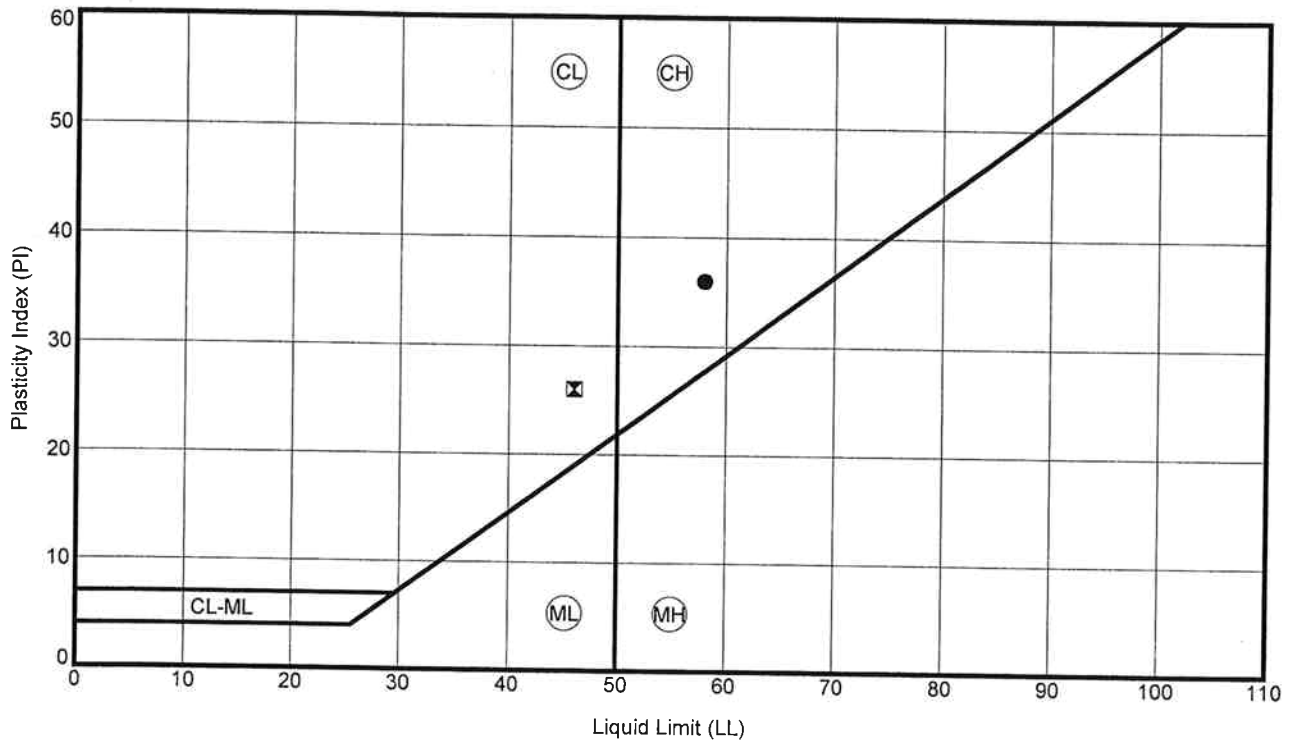


| Cobbles | Gravel | | Sand | | | Silt or Clay |
|---------|--------|------|--------|--------|------|--------------|
| | Coarse | Fine | Coarse | Medium | Fine | |

| Symbol | Exploration Number | Sample Number | Depth (ft) | Natural Moisture (%) | Soil Description | Unified Soil Classification |
|--------|--------------------|---------------|------------|----------------------|------------------|-----------------------------|
| ● | US2-6-01 | D-2 | 15.0 | | Fine sandy SILT | ML |
| ⊗ | US2-6-01 | D-5 | 25.0 | | Silty fine SAND | SM |

| Cobbles | Gravel | | Sand | | | Silt or Clay |
|---------|--------|------|--------|--------|------|--------------|
| | Coarse | Fine | Coarse | Medium | Fine | |

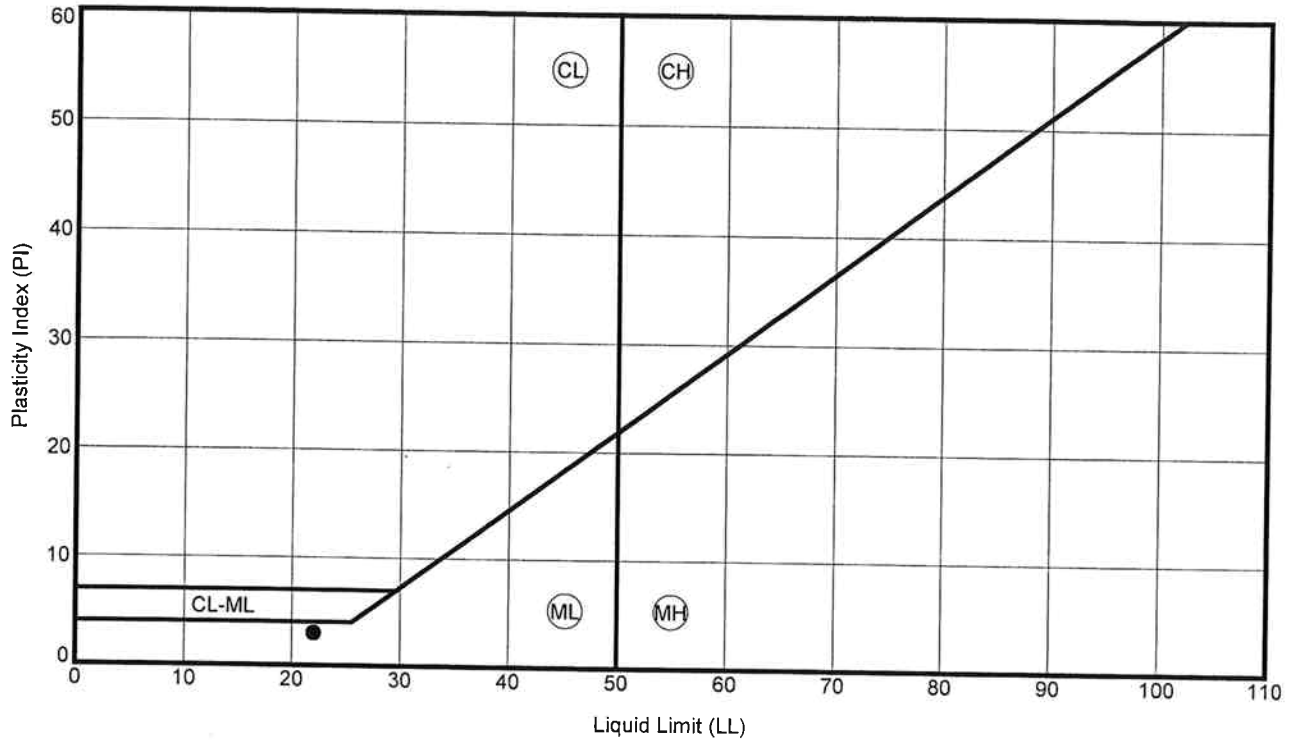
| Symbol | Exploration Number | Sample Number | Depth (ft) | Natural Moisture (%) | Soil Description | Unified Soil Classification |
|--------|--------------------|---------------|------------|----------------------|---------------------------|-----------------------------|
| ● | US2-9-01 | D-8 | 35.0 | | Silty fine to coarse SAND | SM |



ATTERBERG LIMIT TEST RESULTS

| Symbol | Exploration Number | Sample Number | Depth (ft) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | Natural Moisture (%) | Soil Description | Unified Soil Classification |
|--------|--------------------|---------------|------------|------------------|-------------------|----------------------|----------------------|------------------|-----------------------------|
| ● | US2-4D-01 | D-5 | 17.5 | 58 | 22 | 36 | 43 | Fat CLAY | CH |
| ⊠ | US2-4D-01 | D-10 | 30.0 | 46 | 20 | 26 | 30 | Lean CLAY | CL |

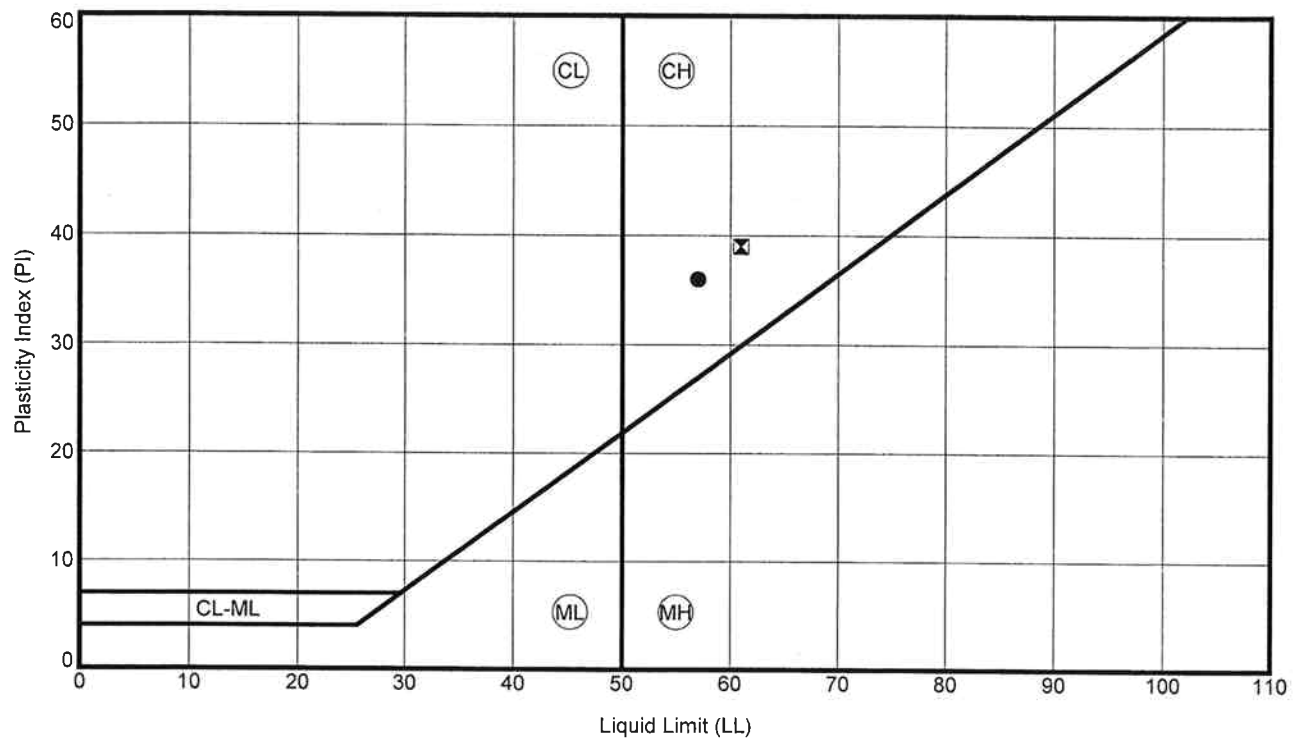
ASTM D 4318 Test Method



ATTERBERG LIMIT TEST RESULTS

| Symbol | Exploration Number | Sample Number | Depth (ft) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | Natural Moisture (%) | Soil Description | Unified Soil Classification |
|--------|--------------------|---------------|------------|------------------|-------------------|----------------------|----------------------|------------------|-----------------------------|
| ● | US2-5-01 | D-9 | 27.5 | 22 | 19 | 3 | 33 | SILT with sand | ML |

ASTM D 4318 Test Method



ATTERBERG LIMIT TEST RESULTS

| Symbol | Exploration Number | Sample Number | Depth (ft) | Liquid Limit (%) | Plastic Limit (%) | Plasticity Index (%) | Natural Moisture (%) | Soil Description | Unified Soil Classification |
|--------|--------------------|---------------|------------|------------------|-------------------|----------------------|----------------------|------------------|-----------------------------|
| ● | US2-6-01 | D-4 | 22.5 | 57 | 21 | 36 | 42 | Fat CLAY | CH |
| ⊗ | US2-6-01 | D-8 | 32.5 | 61 | 22 | 39 | 44 | Fat CLAY | CH |

ASTM D 4318 Test Method

ATTEBERG LIMITS FIGURE C:\PROGRAM-1\GINTW\PROJECTS\US2\GWST\J.GPJ WSDOT.GDT 6/29/01 12:54:11 PM



Analytical Data

Landau Associates

Job Number: A10413AS

Page Number: 2 of 2

Lab Sample ID: A10413AS-1

Field ID: US2GW

Date/Time: 04/11/01 1540

Matrix: Water

EPA Category: Conventional Parameters

| Parameter | Method | Detection Limit | Analytical Result | Units |
|----------------|-----------|--------------------|----------------------|-------|
| Total Cyanide | EPA 335.2 | 0.01 | ND | mg/L |
| Total Fluoride | SM 413-AB | 0.2 | 0.6 | mg/L |

ND means none detected at or above the detection limit listed.



Analytical Data

Landau Associates

Job Number: A10502Z

Page Number: 2 of 2

Lab Sample ID: A10502Z-1

Field ID: US2-9-050101

Date/Time: 05/01/01 1445

Matrix: Water

EPA Category: Microbiological

| Parameter | Method | Detection Limit | Analytical Result | Units |
|----------------|--------------|-----------------|-------------------|---------|
| E. coli | EPA CPRG-MUG | ---- | Absent | /100 ml |
| Total Coliform | EPA CPRG-MUG | ---- | Absent | /100 ml |

EPA Category: Conventional Parameters

| Parameter | Method | Detection Limit | Analytical Result | Units |
|-------------------------|----------------|-----------------|-------------------|-------|
| Ammonia Nitrogen | SM4500NH3BC | 0.2 | ND | mg/L |
| Total Dissolved Solids | EPA 160.1 | 4. | 340. | mg/L |
| Nitrate | EPA 300.0 | 0.2 | 9.2 | mg/L |
| Nitrite | EPA 300.0 | 0.2 | ND | mg/L |
| Total Kjeldahl Nitrogen | SM 4500-Norg-B | 0.2 | ND | mg/L |
| Total Phosphorus | SM 4500-P-B5D | 0.05 | ND | mg/L |

ND means none detected at or above the detection limit listed.



Analytical Data

Landau Associates

Job Number: A10510N

Page Number: 2 of 2

Lab Sample ID: A10510N-1

Field ID: US2-10-01

Date/Time: 05/09/01 1530

Matrix: Water

EPA Category: Microbiological

| Parameter | Method | Detection Limit | Analytical Result | Units |
|----------------|--------------|-----------------|-------------------|---------|
| E. coli | EPA CPRG-MUG | ---- | Absent | /100 ml |
| Total Coliform | EPA CPRG-MUG | ---- | Present | /100 ml |

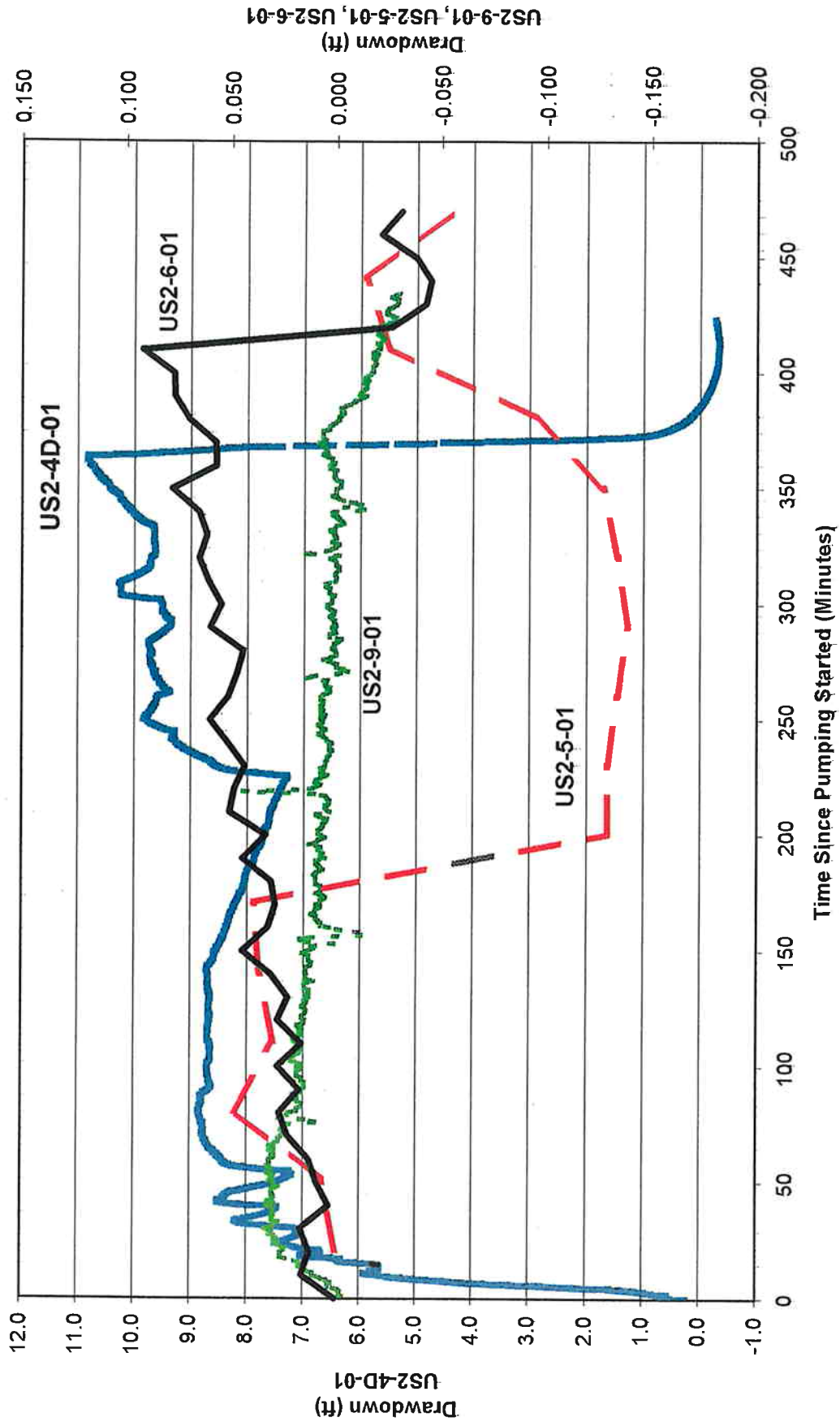
EPA Category: Conventional Parameters

| Parameter | Method | Detection Limit | Analytical Result | Units |
|-------------------------|----------------|-----------------|-------------------|-------|
| Ammonia Nitrogen | SM4500NH3BC | 0.2 | ND | mg/L |
| Total Dissolved Solids | EPA 160.1 | 4. | 150. | mg/L |
| Nitrate | EPA 300.0 | 0.2 | 1.4 | mg/L |
| Nitrite | EPA 300.0 | 0.2 | ND | mg/L |
| Total Kjeldahl Nitrogen | SM 4500-Norg-B | 0.2 | ND | mg/L |
| Total Phosphorus | SM 4500-P-B5D | 0.1 | ND | mg/L |

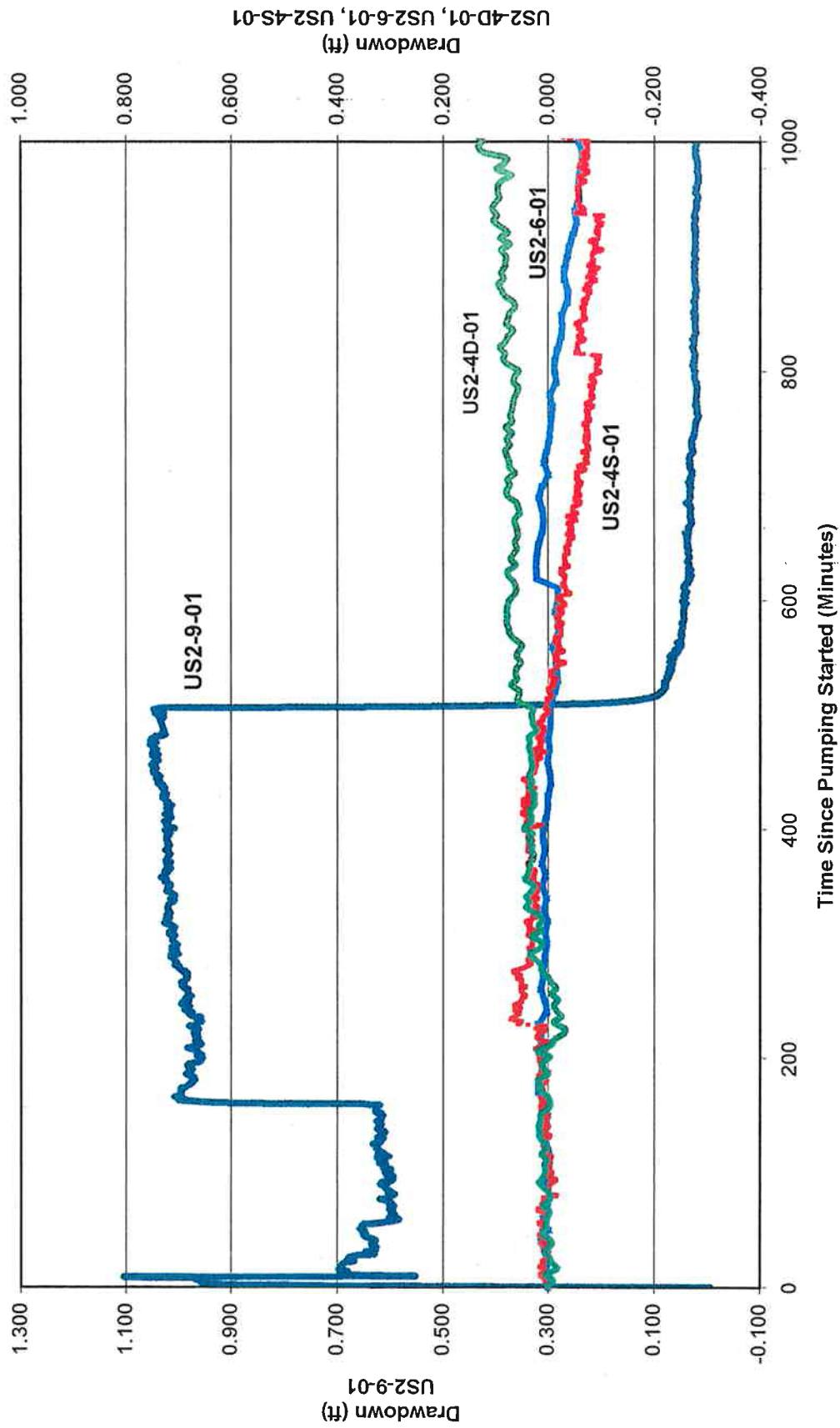
ND means none detected at or above the detection limit listed.

Pumping Test Data

Pumping Well US2-4D-01
Pumping Rate = 0.45 gpm



**Pumping Well US2-9-01
Pumping Rate = 0.8 gpm**



Pumping Well US2-10-01
Pumping Rate = 0.45 - 0.55 gpm

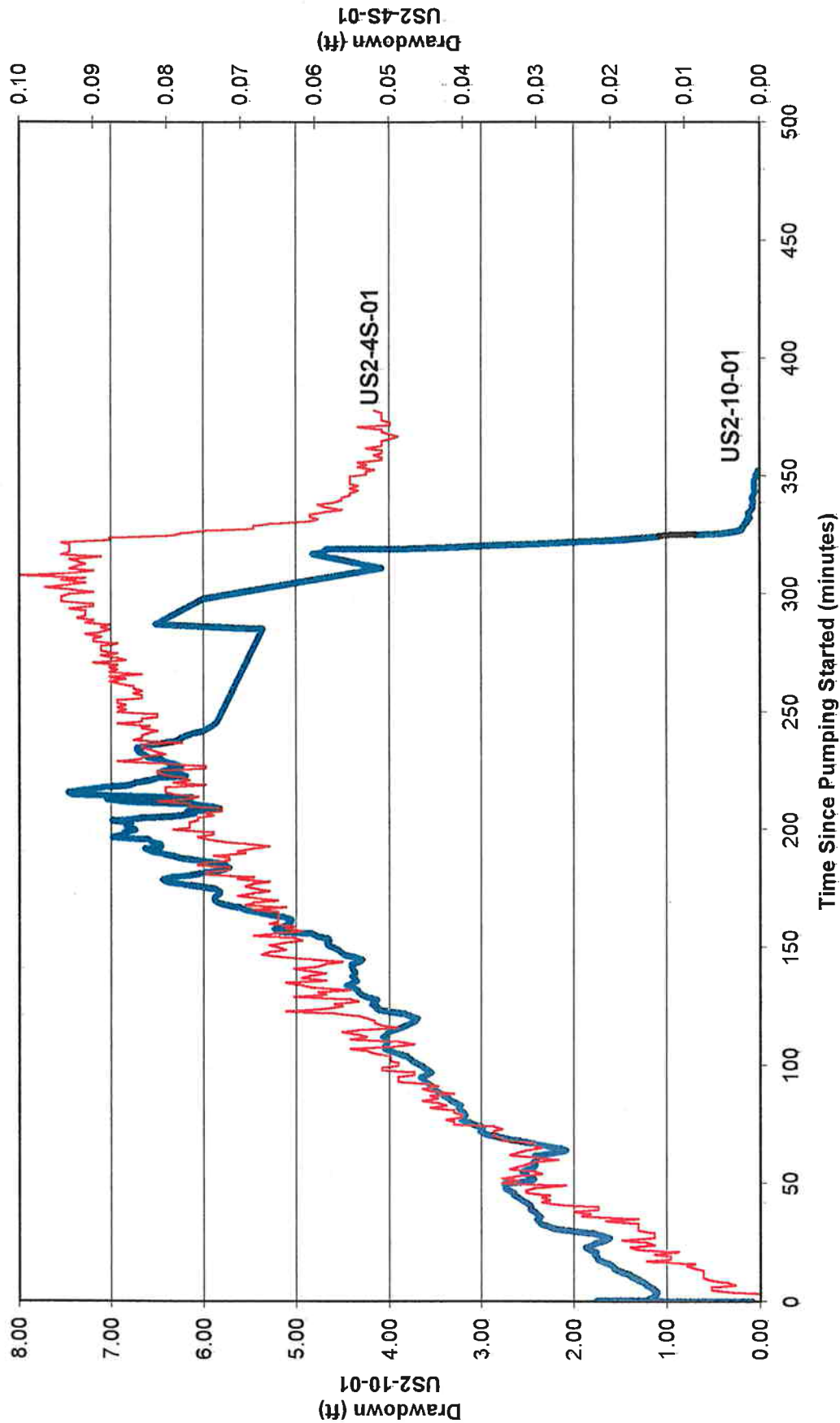


Figure
C-3

Drawdown Versus Time
Pumping Well US2-10-01

SR395 North Spokane
 Corridor Project
 Spokane, Washington